CORNELL EXTENSION BULLETIN 890

POTATO PRODUCTION in New York State

To: *New York State Potato Growers*

New York State's potato industry has undergone many changes throughout the years, especially during the past ten to fifteen years. Other changes and adjustments will be necessary in the future. Growers aware of the needed adjustments and in a position to make them will be able to continue in business and to profit from the efficient production of potatoes.

The College Potato Committee, including representatives of several departments of the New York State Colleges of Agriculture and Home Economics, has seen the need for a bulletin that has in one place the major recommendations to New York State potato growers. No attempt has been made to include in this publication all of the research data and experience that support the recommendations. Growers can be assured that such data and experience exist.

This bulletin is organized on a seasonal basis, following the potato crop from the seed stage to storage and marketing. Members of the Committee and other staff members have prepared individual sections, but all have cooperated in the final presentation.

The College Potato Committee hopes that this bulletin may be helpful not only to the commercial potato industry of this State but to all potato growers.

Sincerely,

The Potato Committee
of the New York State Colleges of
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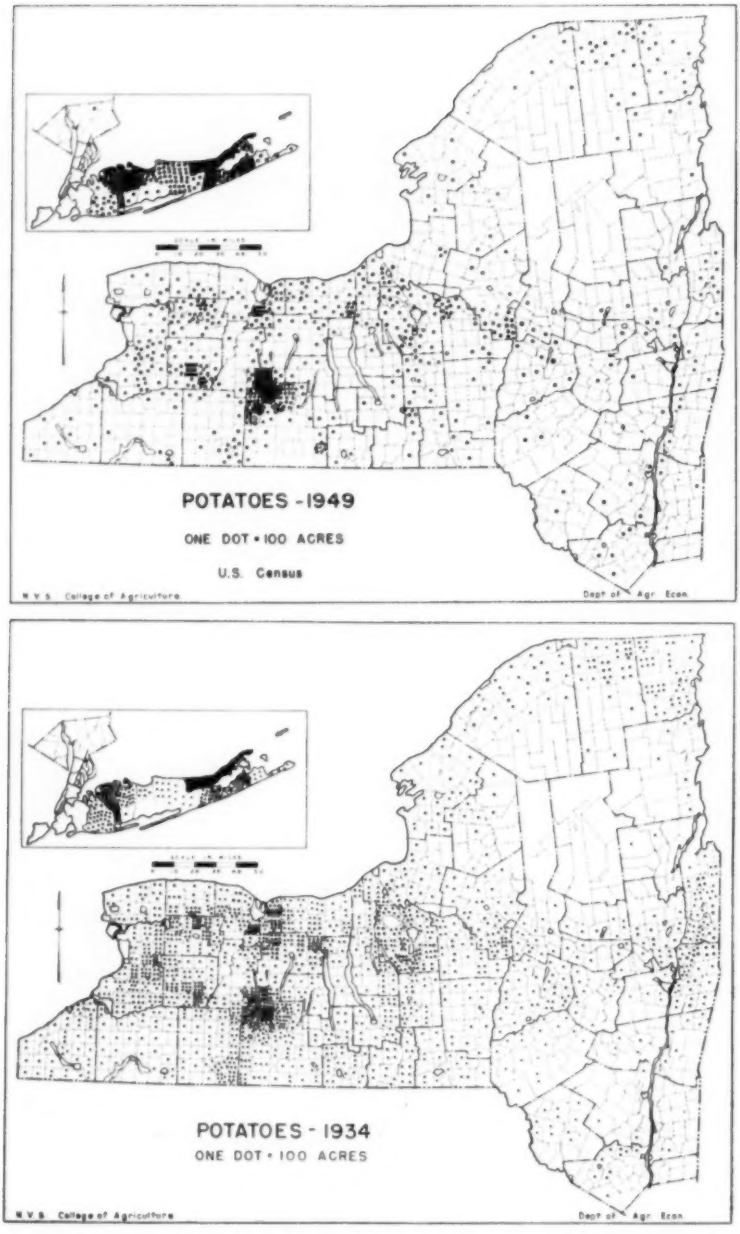


Figure 1. From 1934 to 1949, the potato acreage decreased in most upstate New York areas. During the same 15-year period potato acreage increased on Long Island and in some sections of western New York, especially in northern Steuben County area

Potato Production
in New York State

Economics of Potato Production

GROWING potatoes is serious business today. The Census of Agriculture shows that less than one-third of New York farms are now producing potatoes, as compared with nearly every farm at the beginning of this century. The "patch" of potatoes has almost disappeared in the face of modern technology and of the skill required to produce the relatively good product of today as compared with the potatoes produced by our grandfathers.

Acreage

The acreage of potatoes on New York farms dropped 72 per cent in the first half of this century, but the number of bushels produced was down only 27 per cent.

The change has been tremendous and stimulated by:— developments in transportation, which permit moving perishable commodities over long distances; a rising trend in cost of labor and the accompanying development of expensive labor-saving farm machinery; and the application of results of research which changed and expanded farm operations in potato production and resulted in a much larger yield per acre. Potato production continues to be concentrated in areas where soil and climate are adapted to the production of this crop and in acreages large enough to justify investment in expensive potato equipment for planting, spraying, and digging.

In 1949, potato production on Long Island was about five times the quantity harvested at the turn of the century. About 84 per cent of the farms grew more than 10 acres each of potatoes, and these farms produced more than 99 per cent of the Long Island potatoes. The average acreage for these farms was 48 acres.

Potato production in upstate New York for 1949 was about one-half that of 50 years earlier. The expansion of potato production in the upstate commercial areas was not great enough to offset the dropping out of small acreages formerly grown on nearly 100,000 New York farms. That this trend toward larger acreage of potatoes is not completed is indicated by the Census of 1950 which shows that only 11 per cent of farmers reporting potatoes had 3 acres or more. But these farms with 3 or more acres produced 89 per cent of the total upstate crop.

Yield per acre

Yield per acre is the most important item related to high production efficiency. About as much work and expense is involved in plowing, planting, cultivating, spraying, and digging an acre yielding few potatoes as one with a high yield. The labor for picking, storing, and marketing potatoes depends largely on the number of bushels to be handled, but the costs per bushel of harvesting are usually lower on fields with large yields.

Three decades ago about 1 bushel was obtained for an hour of labor. Potato yields per acre have more than tripled, while the man labor used per acre has changed but little. Consequently, bushels per man hour have about tripled. The wide variations in labor efficiency between growers indicate possibilities of greater efficiency for many growers in this aspect of their operations.

Mechanization of operations on commercial potato farms has not only reduced the man labor requirements per unit; it has made possible, also, prompt timing of the important jobs of planting, spraying, digging, and other operations. Farmers who try to grow potatoes without special machinery and equipment often have a poorer quality product and a higher cost per bushel than do producers who use proper equipment.

Costs of production

Farmers with larger-than-average acreages usually get the higher yields and produce at a lower cost per bushel. A study of 205 farms in Steuben County in 1946 showed only 229 bushels per acre on farms with from 3 to 7 acres of potatoes as compared with 320 bushels per acre on farms with more than 50 acres. The hours of labor per acre were about the same but more fertilizer, more spraying, and more timely operations resulted in a profit of $112 per acre on the larger enterprises as compared with only $36 on the smaller acreages. The producers with the smaller acreages had lower costs per acre but lower yields, higher cost per bushel, and less net profit from the enterprise.

Investment in special potato equipment on seven identical farms increased more than three times in the decade from 1939 to 1949. The need for a large investment in special equipment if one is to get a profit from potatoes is one of the reasons for the continuing trend toward larger acreages per farm in suitable locations.

The cost-account records kept by farmers in cooperation with the New York State College of Agriculture at Cornell show some of the important changes in commercial potato production in New York over the past 40 years. On these farms, average yields per acre increased more

than three times from the World War I period to the 1950's. Hours of man labor per acre changed but little with the increase in yield because growers mechanized their operations. The higher yield per acre and improvements in efficiency resulted in a lower cost per bushel in 1950 than in the 1920's in spite of much higher prices for articles used in production. In the latter year the cost per bushel on these farms, in a year of unusually high yield, varied from 62 cents to $1.06. Owing to a large crop and low prices, three-fourths of these farms had losses in 1950.

In 1949, the average per bushel cost on cost-account farms varied from 70 cents to $1.50 per bushel and prices received varied from 85 cents to $1.37 per bushel. One-fourth of the farms lost money on potatoes.

In the early 1950's, potato growers in upstate New York had about $180 invested in an acre of potatoes at digging time. Harvesting costs varied with the number of bushels to be handled and ranged from $75 to $100 per acre. Storing and selling costs also varied with the number of bushels and with marketing services performed by the grower. These costs ranged from $60 to $75 per acre.

In spite of much labor-saving machinery on potato farms, the labor cost is still about one-third of the total costs of producing and marketing potatoes.

Successful potato growers are always looking for new ideas and trying new ways to do the various jobs more efficiently and more economically. They are alert to varieties and practices that will result in a high yield of uniformly good-quality potatoes. These are matters at least partially within the control of farmers and important to financial success in the potato business.

Soils and Their Management

The right kind of soil is important in potato production. An ideal potato soil is deep and well drained, has a silt loam or a sandy loam texture, and is slightly acid. Such soils can store large amounts of water without becoming saturated or muddy. They are easy to work and they respond to good management. Any soil will, however, become unproductive under poor management. Therefore, regardless of the soil type, it is necessary to: maintain fertility, keep good soil structure, use judgment in tillage, and control erosion.

Fertility

Although the primary function of fertilizer is to supply nutrients for the production of higher yielding crops, it has many other values. On

fertile fields the potato tops soon form a canopy which protects the soil from the beating action of raindrops. This helps to maintain soil structure and reduces erosion. Through fertilization, larger yields can be obtained from fewer acres. This permits seeding soil-building crops on the extra acres. Fertilizer increases the growth and the value of winter cover crops; but nitrogen must be plowed under with the cover crop to produce the desired organic matter.

Structure

Soil with good structure is loose and friable. The surface does not become hard and crusted but remains open so air and water can enter and circulate freely. In a soil with good structure, the individual particles are held together by organic matter to form small aggregates or granules. Granular soil suffers little damage from beating raindrops or from the weight of farm equipment. Although the average potato soil contains less than 3 per cent of organic matter, it is vitally important in maintaining a granular condition.

Soil structure improves under sod. It breaks down under cultivation. To maintain good structure many growers follow a crop rotation of not more than two years of potatoes, one year of grain, and one year of hay. Manure is most beneficial, and a winter cover crop should be a "must." Sawdust, wood chip, or straw mulch is desirable but may be hard to apply.

Soil conditioners may some day supplement organic matter in maintaining soil structure. That day has not arrived and at present such conditioners merely point to the importance of good structure.

Tillage and traffic

Tillage is necessary to prepare a seedbed and to control weeds. The soil compaction that accompanies tillage and other operations is, however, seldom beneficial and may be harmful. On some soils where potatoes are produced each year, plow soles and surface compaction restrict root and water penetration. Most of the unfavorable structure results from the pressure and vibrations of tractor wheels and other farm equipment.

Running a tractor wheel over a Honeoye soil increased the volume weight of the soil from 1.35 to 1.50. The time required for 0.4 of an inch of water to soak into such soil was increased from 2 minutes to 40 minutes. When the tractor wheel was run over the soil under wet conditions, the soil became almost impervious to water. In both tests the compacted zone extended several inches below the furrow slice.

Figure 2. A rye seeding attachment mounted on a potato digger

No satisfactory tillage method has been devised to loosen compacted soil. Deep tillage tools apparently have little lasting effect. Maintaining the area in sod for several years would help, but, on most farms, this would be impractical. Growing legumes in rotation or plowing down nitrogen with grass sod offers much promise.

Prevention seems to offer the most promise. Many growers fit land more than is necessary, and equal or better yields could be obtained from less harrowing. Fields with high organic content show little compaction. There is less damage when the soil is fairly dry. Therefore, to be on the safe side, one should fit fields no more than is necessary, should maintain high organic level, and should stay off land when it is wet.

Erosion

Good soil recovers from past mismanagement rather rapidly, so a moderate amount of past erosion may not make a field unsuitable for potatoes. But it is practically impossible to build up a soil if erosion is permitted to continue, because the steady removal of the finer and more fertile soil particles offsets the benefits of fertilizer and other treatments.

The water that runs off the field and causes erosion may, however, be a greater loss for any one crop than the loss of the soil itself. A few

years ago, when 200 bushels of potatoes per acre was considered a big yield, water was seldom a limiting factor. But now, when one strives for larger yields, moisture is the *most important* "fertilizer." More than 300 pounds of water are required to make 1 pound of dry matter, and a rapidly growing crop of potatoes needs 1½ inches of water each week. Normal summer rainfall does not supply this amount, but a well-managed soil will store water that falls at other seasons and hold it in available reserve until the time of need.

Good soil structure, organic matter, and adequate cover are effective in controlling erosion and storing water. But if the land has much slope, other treatments are needed. Planting on the contour or, better still, strip-cropping, whereby potatoes are produced between alternate strips of a close-growing crop effectively reduces erosion and increases yields. Diversion terraces are needed on long slopes. Further information on these practices is given in Cornell Extension Bulletins 800, *Contour Strip-Cropping* and 808, *Diversion Terraces.*

Rotations

Until about fifteen years ago the most common potato rotation in upstate New York was one of four or five years in length, with from two to three years of some hay sod immediately preceding the potatoes. Organic matter was rather easily maintained at a fairly high level with this practice. It meant, however, that potatoes were grown on many soils that probably were not well suited for that purpose. Shorter rotations, or the growing of potatoes on the same area each year, would make it possible to select the best potato soils on the farm. The prevalence of tuber insects and diseases in the long rotations, particularly in potatoes following leguminous or grass sods, has made it highly desirable to abandon these rotations in favor of shorter ones.

On Long Island, most potatoes are grown on the same area each year with a cover crop of rye seeded just after harvest. Potatoes are also rotated with various other vegetable crops.

In upstate New York, potatoes have responded in various ways to rotations, depending somewhat on type of soil, on the fertility level maintained, and on location. In the southern tier counties of western New York on quite acid soils, large increases in potato yields were obtained by applications of manure in addition to commercial fertilizer. Highest yields were in plots where potatoes were grown every year in the same area or in two-year rotations with clover and timothy or one of the millets. In central-western New York in soils more nearly neutral, high yields were obtained in a two-year rotation of potatoes with rye cover and dry shell beans with rye cover. Another high-yielding

two-year rotation was potatoes with rye cover followed by corn for green manure followed by rye cover.

A fairly common and high-yielding rotation in western New York is one of two years, potatoes followed by wheat or oats (seeded) and combined. No hay is removed from the area; the entire growth, with stubble and straw from combining, is plowed under for the next crop of potatoes.

Sanitation for Disease Control

SANITARY practices are recommended as part of the control program for practically every crop disease. Often the proper disposal of diseased plant parts and the frequent cleaning and disinfecting of equipment are the cheapest, yet the most effective, disease-control measures. Sanitation is especially important in combating late blight, ring rot, and the golden nematode disease – three important potato diseases.

Late blight

The sprouts from discarded blighted tubers in a cull pile often have millions of spores on them. These spores can be carried by winds for ¼ mile or more to a potato field. Many severe late-blight infestations have been started from cull piles.

Spreading blighted tubers on the ground and allowing them to freeze is one of the cheapest and easiest ways to dispose of them. If the blighted tubers that have been dumped in a pile have not sprouted, a sprout inhibitor, such as sodium chlorate, can be applied to prevent their growth. If, however, some of the tubers are sprouting, a thorough drenching with an herbicide will kill the sprouts. Burial is effective when the soil covering is at least from 1½ to 2 feet deep. Straw, gasoline, or fuel oil can be used to burn them, but each tuber must be well cooked. Regardless of the methods used, periodical inspections of the pile should be made and any sprouts that appear cut out in spite of previous treatment.

Ring Rot

In controlling ring rot, it is necessary to destroy the tiny bacteria that cause the disease. Of the several ways to do it, some are:

1. To dispose of all potatoes from crops in which ring rot has been found. They may be sold or used for table stock but not for seed.
2. To clean up storages and equipment with a good disinfectant. Planters, diggers, washers, graders, bags, crates, baskets, and all storage surfaces that have come in contact with diseased potatoes should be cleaned. The following disinfectants have been recommended:

Copper sulfate — 2 pounds to 10 gallons of water
Mercuric chloride (corrosive sublimate) — 2 tablets in 1 pint of water to make 1:500 solution
Formaldehyde — 1 pint of 40 per cent product to 15 gallons of water
Cresol (lysol) — 1 gallon to 25 gallons of water
Steam or boiling water

3. To use certified seed.
4. To disinfest the cutting knife. If a machine is used, it should be thoroughly cleaned and disinfested between lots and preferably once a day. Some device for continuous disinfestation of the cutting knife reduces the rapidity of multiplication of the disease.
5. To rotate. Under certain conditions, the ring-rot bacteria possibly can be carried over in volunteer plants from tubers left in the field.

Golden nematode disease

The golden nematode is a pest recently introduced to this country. It is found only in limited parts of Long Island and in one field in New Jersey. The infestation in New Jersey resulted from the use of debris from used burlap bags as fertilizer. Profitable crops of potatoes cannot be grown when large numbers of golden nematodes are present in the soil. The disease is discussed in Cornell Extension Bulletin 870, *The Golden Nematode.*

Golden nematodes spread chiefly through the movement of infested soil in the production and marketing of potatoes and of other agricultural crops. To prevent the introduction of the golden nematode onto any farm, the following precautions should be taken:

1. If possible, bring only new bags, crates, and machinery onto the farm.
2. Treat newly purchased used bags, crates, and machinery with methyl bromide before they reach the farm. How to do this is told in Cornell Extension Bulletin 866, *To Prevent the Spread of Golden Nematode of Potatoes, Disinfest Burlap Bags and Machinery with Methyl Bromide.*
3. Do not return any soil from central grading stations to the farm.
4. Rotate crops on potato land. Do not include tomatoes, which also are attacked by this nematode, in the rotation.

Wireworms and Their Control

The growing tubers may be injured by wireworms as they bore holes into them. Three or four holes in a potato may throw it out of grade. In severe infestations, from 100 to 150 holes may be found in one

potato (figures 3 and 4). Such a potato is worthless.

Wireworms are the immature stage of click beetles. Two kinds are pests in New York. The *wheat wireworm* requires three years to complete its growth. It develops on the roots of sod grasses. When the sod is plowed under and the land planted to potatoes, the wireworms feed upon the potato roots and later in the season feed in the tubers. The *sand wireworm* completes its growth in one year. It can be an annual pest without any relation to a sod soil. It seems to prefer sandy soil for its growth.

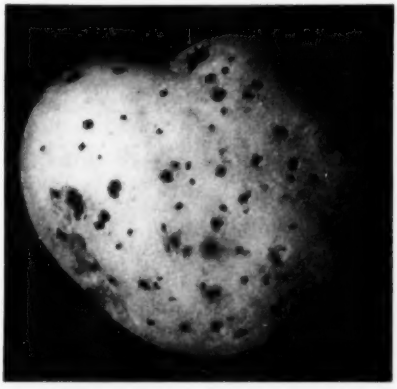
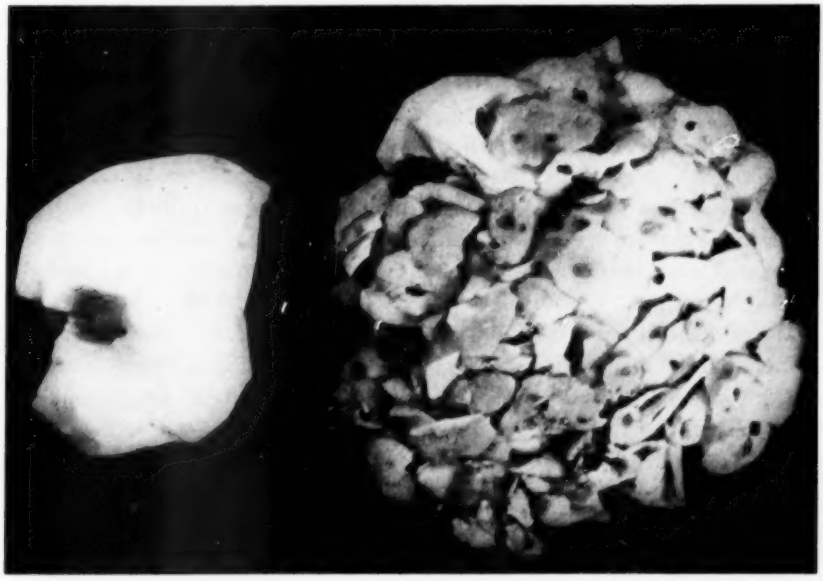


Figure 3. Potato showing wireworm injury

One can prevent injury by the wheat wireworm in two ways: (1) never plant potatoes in a field that was in sod the previous year, or (2) treat the soil at fitting time with an insecticide. This last method is the only satisfactory way to control the sand wireworm.

Not all sod lands are infested with wireworms. Sometimes only

Figure 4. The same potato as that in figure 3 and the peeling waste preparatory to cooking



a part of a field with perhaps a different moisture content is infested. Since the wheat wireworm requires three years to complete its growth, it follows that a plowed sod will have some wireworms in it of three sizes and there will be some in it the third year. It is best, therefore, not to plant potatoes following a sod for two or three years but to grow a crop such as corn or beans instead. This is especially true if the sod is an old one. The wireworm population will be low the third year to the point where the injury to potato tubers ought not be severe.

When control of wireworms by crop rotation is not practical, an insecticide, either heptachlor or chlordane, may be used. Heptachlor is cheaper, and can be used as liquid or powder spray.

Two pounds of actual heptachlor are needed per acre. One gallon of an emulsion usually contains exactly 2 pounds of heptachlor. Hence 1 gallon of the emulsion would uniformly cover one acre. This can be done either in a high-pressure sprayer or in a low-pressure weed type of sprayer. The quantity of water per acre is immaterial. If one uses a 50 per cent wettable powder of heptachlor, 4 pounds are needed for each acre. This is applied best with a high-pressure sprayer.

A dust form of heptachlor may be applied by a dusting machine. If it is a 5 per cent strength, 40 pounds will be needed for each acre.

Fertilizer dealers may offer the insecticide already mixed in fertilizer to be put in the soil before or after plowing. This method of distributing the heptachlor is not strongly recommended. It is important to know just exactly how much of the actual chemical is being put on per acre and to put it on uniformly. A heavy amount in one place might give an off-flavor, while a light treatment in another might not give control.

The insecticide is best applied to the soil surface in spring before plowing. It can be applied at that time to fall-plowed land. It is worked into the soil to a depth of 3 to 4 inches. It can be applied also just after the potatoes are planted when one can see the rows, but perhaps it cannot then be so readily worked into the soil as when it is applied before planting.

When chlordane is used, 6 pounds of the actual insecticide are needed per acre. This means 6 quarts of the 42 to 44 per cent strength of an emulsion, which contains 4 pounds of actual chlordane per gallon, or 3 quarts of the 72 to 74 per cent strength of an emulsion, which contains 8 pounds of actual chlordane per gallon. The emulsions mix readily in water as a milky solution.

If the wettable powder forms of chlordane are used, then 12 pounds of a 50 per cent strength, or 15 pounds of a 40 per cent strength, are

needed for each acre. Should one use a 5 per cent dust of chlordane, then 120 pounds must be applied uniformly per acre.

A single treatment with one of these chemicals ought to give control of both kinds of wireworms for from two to five years. Both have undetermined lasting effectiveness. Both might be expected to control in part the immature stages of other potato insects, such as the Colorado potato beetle and the larval stage of flea beetles, since these also spend a part of their life cycle near the roots of potato plants.

Another insecticide, known as aldrin, has just been approved for use in soil to control wireworms that may attack potato tubers. It may be used at manufacturer's directions.

Common Scab Control

THE common scab disease is apt to be prevalent in soils more alkaline than pH 5.4, and seldom in soils with a pH reading of 5.2 or less. Certain practices can be employed to reduce the severity of the disease. Symptoms are discussed under *Other Diseases* (page 34).

Very scabby tubers should not be used for seed, because the eyes may be injured or weak and more virulent scab organisms would be introduced into the soil. The application of lime, ashes, fresh barnyard manure, nitrate of soda, or calcium cyanamide to potato soils favors scab because they tend to increase the alkalinity of the soil. Acid fertilizers, such as those incorporating ammonium sulfate or superphosphate, help to reduce the amount of scab, especially if used for several years. Applications of sulfur can be made in certain instances. Usually, the effects of a sulfur application are not observed until the following year, and too much can reduce yield. A yearly soil analysis is valuable when using these materials. The analysis includes a pH, or soil acidity, reading that helps to prevent the development of a deleterious soil-acidity condition.

More organic matter should be incorporated in sandy or gravelly soils in which scab is prevalent. This can be accomplished by plowing under green cover crops, such as rye or millet. A rotation of six to seven years is beneficial if root crops or those crops that require lime are not used.

Common scab is more severe in dry than in wet seasons. Generally less scab is observed when the potato soils have had an adequate supply of moisture at the time of tuber formation.

Seed treatment is advisable when planting scabby tubers in new or non-infested potato soils. A formaldehyde treatment (page 22) is preferable since mercurial seed treatments seem to aggrevate the disease.

The planting of a resistant variety (pages 17 and 18) should be considered for highly infested soils.

Choice of Variety

In recent years considerable progress has been made in breeding potato varieties that are superior in yielding ability, disease resistance, culinary quality, and appearance. To date, however, only several of these desirable characteristics have been incorporated into a single variety. This accounts for the fact that one finds a rather confusing array of potato varieties in the potato-growing sections of New York and of the United States.

The grower would be wise in his choice to consider the older varieties that have become well established through grower acceptance, taking into consideration the varieties grown under similar conditions as they exist in his locality. Certainly one should try the new and very new on a small scale, but should not go "overboard." It takes a good many growing seasons to subject a variety to a certain set of conditions that brings out faults which are often rather serious.

Usual varieties

Chippewa. Medium early; tuber, oval-flattened; skin, white and smooth; eyes, few and shallow; flesh, soggy; stores poorly; susceptible to scab, late blight, and leaf roll.

The variety is marketed as an early and late crop potato. The tubers are attractive, maintaining their shape under adverse growing conditions. Yields are usually average.

Cobbler. Early; tuber, cubical; skin, white and smooth; eyes, many and deep; flesh, fairly mealy; stores well; susceptible to scab and late blight.

A very popular early variety which is best sold as such and not allowed to compete with late varieties. Tubers tend to be rough and become very rough under adverse growing conditions. Yields usually lower than Chippewa.

Green Mountain. Late; tuber, oblong-flattened; skin, creamy white and patchy netted; eyes, many and medium depth; flesh, very mealy; stores well; susceptible to scab and late blight.

Green Mountain, despite its excellent baking quality, is decreasing in acreage primarily because of a marked tendency to produce ill-shaped, knobby tubers under adverse conditions. Yields of marketable tubers are high under good growing conditions.

Katahdin. Midseason; tubers oblong, rounded; skin, white and smooth; eyes, few and shallow; flesh, fairly mealy; stores well; susceptible to scab and late blight.

Katahdin is by far the most important variety in New York, accounting for approximately one-half the acreage. The variety is not particularly outstanding in yielding ability, disease resistance, or cooking quality. Its popularity can be attributed to dependability in producing a fair crop under very adverse growing conditions. Tubers are very attractive and for that reason preferred by retailers, wholesalers, and consumers.

Primary objections to the variety are its shy set and consequent production of too many large potatoes. The tubers set too near the ground level, resulting in a substantial percentage of sunburned tubers.

Kennebec. Midseason; tubers, oblong and rounded; skin smooth and white; eyes medium in number and depth; flesh, mealy; stores well; very resistant to late blight; susceptible to scab, verticillium wilt, and spindle tuber.

One of the newer varieties that is gaining in acreage, produces very high yields of attractive, excellent culinary-quality potatoes.

This variety sets few tubers per plant and produces a very high proportion of rough, oversize tubers. Spacing of seed closer together and use of vine killers are helpful.

Ontario. Very late; tubers, oblong and flattened; skin, white and smooth; eyes, medium in number and shallow; flesh, soggy; stores well; very resistant to scab, susceptible to late blight and leaf roll and very susceptible to pressure bruise or black spot.

Ontario produces very high yields of fairly attractive tubers under good growing conditions but is susceptible to heat sprouting, knobbiness, and production of chains of tubers under hot, dry conditions.

The variety should be grown only where a scab problem exists. Tubers usually sell at a discount as compared with those of Katahdin.

Pontiac. Late; tuber, oval and rounded; skin, dark red and smooth; eyes, many and medium in depth; flesh, soggy; stores well; susceptible to late blight and scab.

A very high-yielding variety that is grown for special markets desiring a red-skinned potato. Under adverse conditions the tubers heat sprout, crack, and produce knobs.

Rural (Smooth and Russet). Late; tubers, oval and flattened; skin, smooth and white or dark russet; eyes, few and medium in depth; flesh, mealy; stores well; susceptible to late blight and "Z" disease. The Russet Rural has some resistance to scab.

Highly desirable varieties for chipping purposes because of their ability to recondition after being kept at storage temperature producing a desired color chip. These varieties are seldom offered for sale as

table stock although they are excellent bakers.

Yields are usually below average and a very high percentage of the tubers are off-grade because of growth cracks, knobs, and dumbbells under adverse growing conditions.

Sebago. Late; tuber, oval and rounded; skin, white and smooth; eyes, of medium depth and shallow; flesh, fairly mealy; stores fairly well; some resistance to scab and late blight; susceptible to verticillium wilt and fusarium storage rot.

A better than average yielder with tubers of good table quality. Primary reason for Sebago not increasing in acreage is because of fusarium storage rot that results from handling this late crop while still immature.

Other varieties

Other varieties which are worthy of mention and could be tried on a small scale are as follows:

Canoga. A very late, white, smooth-skinned, high-yielding variety of good table quality. Susceptible to scab, leaf roll, and late blight.

Cherokee. A medium early, smooth, white-skinned variety of average yield and table quality. The variety has a high degree of resistance to late blight and scab. Susceptible to second growth and rough tubers under adverse conditions.

Essex. A midseason, white-skinned, very high-yielding variety of poor table quality under most conditions. Essex is resistant to late blight but susceptible to scab and air cracking when dug immature.

Houma. A midseason, white-skinned variety yielding an average crop of excellent quality potatoes. Susceptible to leaf roll, scab, and late blight.

Seed and Seed Handling

For best results, certified seed or seed known to be relatively free of virus diseases should be planted.

Chemical seed treatment to control seed-borne diseases is not so practical in this State as in past years. Only on Long Island is seed treatment still practiced to any great extent (page 21).

Every year many growers have poor stands of potatoes. Probably the most common cause for the failure of plants to emerge is the decay of the cut seed pieces before the young plant is large enough to manufacture its own food and exist without further help from the mother tuber. Other causes are planting dormant seed, planting seed pieces too small, planting weak-eyed seed pieces from the stem ends of tubers of some varieties such as Sebago, and injury from rhizoctonia.

Storage temperature

The temperature at which potatoes are stored, especially during the last few weeks of storage, has a marked effect on sprout growth, rate of comeup, stand, and yield. Plants from potatoes stored at various temperatures appear aboveground in the following order: first, those stored at 50° F. followed by those stored at 40°, 35°, and 32° F. Final stand of plants is usually lower from seed that has been stored at 32° F. than from seed stored at higher temperatures. At 32° F. the seed is dormant; at temperatures of 40° F. or above the seed has sprouted by planting time. The most tubers per plant, as well as the most U.S. 1 size tubers, were formed from seed that had been stored at temperatures that resulted in sprouts at planting time. It is, therefore, advisable to store seed at 45° to 50° F. for several weeks before planting. Sprout growth at planting time should be at the greatest possible number of eyes, but the sprouts should not be so long that their tips would be badly damaged or broken off during the planting operations.

Removal of sprouts from seed

Many growers are undecided whether or not to remove the sprouts from tubers before planting. The resultant yields from tubers depend upon the extent of sprout growth at planting time. If long sprouts are removed a week or two before planting, and other short sprouts have replaced them by planting time, there is little or no difference in comeup and yields between those from which the sprouts have been removed and those with sprouts uninjured. Most decreased yields from desprouted tubers have resulted from sprout removal just before planting and, therefore, have been due to a difference in sprout length at planting time and not to a weakening of the tubers. Apparently seed pieces are not greatly weakened by the removal of sprouts unless they have been desprouted four or five times.

Early in the season when apical dominance is prominent, as shown by one strong sprout on the bud end of each tuber, it may be advantageous to remove these sprouts, for usually they are replaced by a greater number than those removed. This results in a larger number of stems to each seed piece and usually in a greater number of tubers to each plant. This may or may not be desirable, depending upon variety, soil moisture, soil fertility, fertilization, and size of tubers desired. Usually the heavier the set of tubers, the smaller the average size of those tubers. This may be best in the production of seed potatoes or of table stock of varieties that set few tubers, such as Kennebec and Katahdin.

Greensprouting seed

Results of many experiments show that yields have not been increased by greensprouting seed as compared with yields from seed not exposed to light but otherwise treated the same as the greened seed. Generally less work is required to warm the seed in storage without an extra handling than is required to greensprout the seed, and results are as effective as is greensprouting. It is recommended that the grower use the method most convenient for him.

Hot, chemical seed treatment

Seed potatoes of older varieties have been treated with various hot chemicals with no apparent weakening of the eyes. In these older varieties, such as Rurals, Green Mountain and Irish Cobbler, the eyes in the stem ends of the tubers apparently are as strong as those from the bud ends. Usually no injury results in these varieties from hot chemical treatments properly used. With some of the newer varieties, such as Chippewa, Sebago, and possibly others, eyes in the stem end of the tubers are weaker than those near the bud end. These weak stem-end eyes sometimes are further weakened by the hot, chemical seed treatment resulting in lower stands of plants. Hot, chemical seed treatment is not extensively practiced in New York State in recent years. It is recommended that the hot treatment not be used on such varieties as Chippewa and Sebago.

Cutting seed

Whole or cut seed

Many times planted whole seed results in larger yields than the same amount of cut seed from larger tubers, largely because of higher stands of plants or of less seed-piece decay from the whole-seed plantings. By using the same weight of seed pieces, whole seed usually produces more tubers per plant than does cut seed. This could be of value to growers of seed potatoes and of those growing varieties such as Kennebec and Katahdin, which set few tubers and results in too many large potatoes.

Size of seed piece

The larger the seed piece, in general, the greater is the number of tubers set per hill. Hence it is usually advantageous to plant large seed for production of seed potatoes and especially when growing such varieties as Katahdin and Kennebec. Smaller seed would probably be advisable when growing heavy-setting varieties such as Houma and Essex.

The best size of seed piece to use also depends somewhat on the

distance between seed in the row. Recent experiments show that where fertility level is high and moisture content of the soil is not too limiting, greatest returns per acre from 9-inch spacing has been from seed pieces of about 2 ounces in weight rather than smaller. If whole seed are planted, this would be of the size 1½ to 1⅞ inches. Most seed growers probably should use 6- to 8-inch spacing. Under most conditions nothing smaller than 1½-inch seed should be planted; this would average about 1½ ounces per tuber.

Curing cut seed

The best practical method to prevent seed-piece decay of cut tubers is to cure the pieces before planting. This method is practiced extensively on Long Island and enables the growers to cut seed in advance when field work is not possible.

Cut potatoes should be placed in crates or some other well-aerated containers (not bags) which are stacked with some space between the tiers of crates for ventilation. It is best to maintain the temperature of the air surrounding the crates at 55° to 65° F., and it is essential to keep the air very moist, at least 90 per cent relative humidity, if possible, for cork to form over the cut surface. Water may be applied to the walls and floor of the storage room and sacks soaked in water and placed over the tops of crates and between the stacks of crates to help maintain proper humidity. Cut tubers should remain under these conditions for at least from three to six days; longer if possible or necessary, then placed at 40° to 50° F.

Lime, sulfur dust, or any similar material should not be applied to freshly cut seed.

Properly cured seed pieces may be held safely for several weeks should it be necessary, because of weather or other poor planting conditions.

Seed Treatment

Seed treatment is used to disinfest the surface of the tubers before they are planted. The treatment does not control the internally borne causative agents of disease. The practice of seed treatment is advantageous when planting tubers in new or non-infested soils, especially if the tubers have rhizoctonia, fusarium, or common scab organisms on the surface.

It is preferable to treat only whole uncut tubers that have few sprouts. Old containers also should be treated before the disinfested tubers are returned to them or at the same time as treating the tubers.

The seed-treating materials discussed in the following paragraphs have been satisfactorily used and are recommended for this purpose. Other methods and chemicals are continually being tested to determine their value as dips or dusts for seed treatment.

Common scab (limestone areas)

The tubers can be soaked for 1½ to 2 hours in a cold solution consisting of 1 pint of commercial formaldehyde in 30 gallons of water. The tubers should be drained and dried immediately.

A hot dip can be used by mixing 2 pints of commercial formaldehyde in 30 gallons of water, and keeping the solution at 124° to 126° F. The tubers are dipped for 2½ to 3 minutes, drained, covered for an hour, and then immediately dried. Some varieties are injured by hot dips (page 20).

Fusarium seed-piece decay

A dip can be prepared by mixing one of the following materials in 30 gallons of water: 1 pound of yellow oxide of mercury, 4 pounds of Semesan Bel, or 1 pint of a nabam (Dithane D-14, liquid Parzate, and others). The tubers should be immersed and the container rotated so that all surfaces are covered.

Rhizoctonia

The yellow oxide of mercury dip has been used successfully as a seed treatment for rhizoctonia.

A cold mercuric chloride (corrosive sublimate) solution also can be used. The solution is prepared by mixing 4 ounces of mercuric chloride in 30 gallons of water. The tubers are soaked for from 30 minutes to 2 hours, and then dried.

The seed-treating solution employing mercuric chloride should be prepared and used in a glass, wooden, earthenware, or concrete container. The mercury compounds are poisonous and the treated tubers must not be used as table stock or feed for livestock.

Fertilization

THE potato plant, in producing a good crop of tubers, utilizes large quantities of the various elements necessary for growth. A number of these elements are available in the soil in sufficient quantity to provide the plants' needs. Other elements, notably nitrogen, phosphorus, potassium, and very often magnesium, are not available in sufficient quantity and must be supplied in manures or chemical fertilizers.

In recent years, mechanization and intensification on potato farms has so greatly reduced the use of manures that on many farms chemical fertilizers are being used exclusively.

Fertilizers are a relatively cheap item in producing a potato crop and, within reasonable limits, the use of excessive amounts has no detrimental effects upon yield.

The results of three years (1950 to 1952) experimental work on upstate soils with the varieties Katahdin, Sebago, Russet, and Smooth Rural showed no decrease in yield where excessive amounts of nitrogen, phosphorus, and potash were used.

Results on Long Island with Cobbler, Green Mountain, and Katahdin were similar with the exception that yields for Green Mountain decreased where excessive amounts of phosphorus were used.

Soil tests

Fertilizers are not used to supply all the elements required by the potato plant but are a supplement to those supplied by the soil. Soil type, pH, crop rotation, past fertilization practices, and the like influence the quantity of elements that the soil is capable of supplying.

Recent research on Long Island and in upstate New York has indicated that previously heavily fertilized soils have accumulated rather large quantities of phosphorus and potash so that less of these elements needs to be applied in the mixed fertilizers. Equivalent yields have been attained by the use of an 8–8–8 fertilizer as compared with an 8–16–16, and the 8–8–8 is cheaper.

Since it is virtually impossible for the grower to know the availability of the various elements, he must rely upon soil tests. The agronomy department's Soil Testing Laboratory at Cornell University, for a nominal fee, will test soil samples for growers. The results of these tests will be interpreted by a specialist and recommendations made regarding the amount and kind of fertilizer materials to use to attain maximum yields.

It is important that the soils being tested are adequately sampled, which requires the services of trained personnel. County agricultural agents are qualified to do such work and should be consulted.

Samples should be taken well in advance of the time that fertilizer materials are to be ordered.

Chemical or mixed fertilizers

Mixed fertilizers for potatoes contain nitrogen, phosphorus, and potassium in forms that are available to the plant. These elements are expressed as percentages; for instance, 1 ton of 5–10–10 fertilizer contains 100 pounds of nitrogen (N), 200 pounds of phosphorus (P_2O_5), and 200 pounds of potassium (K_2O).

On upstate New York mineral soils it is profitable to apply in a mixed fertilizer from 120 to 150 pounds of nitrogen per acre, on Long Island from 125 to 140 pounds per acre, on new muck from 90 to 100 pounds per acre, and on old muck from 100 to 110 pounds per acre.

The amount of phosphorus and potash to apply depends upon the fertilizer analysis.

Growers on upstate mineral soils more often use a 1–2–2 ratio fertilizer, such as a 5–10–10 or 8–16–16. Other ratios are a 1–2–1 (5–10–5 or 6–12–6), 1–2–3 ratio (5–10–15), 1–1–1 ratio (7–7–7, 8–8–8, 10–10–10).

Long Island growers use a 1–2–1 ratio primarily of a neutral 5–10–5 analysis; because most Long Island soils border on the too acid side and, since most mixed fertilizers are acid, lime is added to give a neutral reaction. A neutral 1–1–1 ratio is now being used to some extent.

For new muck, a 1–2–1 ratio fertilizer is recommended; for old muck, a 1–2–2 ratio. Ratios are discussed in Cornell Extension Bulletin 855, *Fertilizer Recommendations for the Commercial Production of Vegetable Crops.*

Magnesium

Mineral soils with a pH lower than 5.5 are often deficient in magnesium. To correct this deficiency, from 40 to 50 pounds of soluble magnesium, expressed as magnesium oxide, should be applied per acre. It is more convenient for the grower to have this magnesium incorporated into the mixed fertilizer.

On magnesium-deficient soils, it would be advantageous when applying lime to use a high magnesium lime, such as dolomitic limestone, provided there is no great difference in price favoring high-calcium lime. The quantities used and the availability of magnesium in dolomitic limestone is not likely to warrant elimination of soluble magnesium from the mixed fertilizer.

Manure

Aside from the fact that manure tends to aggravate a scab problem (page 15), it makes an excellent fertilizer and has the added advantage of adding organic matter to the soil.

Ten tons of cow manure to which 250 pounds of superphosphate has been added (cow manure is deficient in phosphorus) contains about 88 pounds of nitrogen (N), 80 pounds of phosphorus (P_2O_5), and 80 pounds of potash (K_2O). When this amount of manure has been added to an acre of land, the grower would be justified to reduce the mixed fertilizer application by about one-third.

Sod and cover crops

A grass sod or rye cover crop plowed under prior to planting potatoes competes, in its decomposition, with the potato plants for nitrogen. Under these conditions, a nitrogen top-dressing should be applied to the sod prior to plowing. About 50 pounds of nitrogen per acre should be applied if the sod or cover crop is heavy or about 30 pounds if light.

A good legume sod actually liberates nitrogen for use of the potato crop and can be expected to furnish from 25 to 50 pounds of nitrogen per acre during the first year.

Nitrogen side dressing

Under normal conditions a nitrogen side-dressing is not profitable, provided enough fertilizer was applied at planting time. Some years, however, on light soils excessive rainfall, especially during the early part of the season, will result in enough leaching to cause a nitrogen deficiency. Under these conditions, it would be advisable to apply from 20 to 30 pounds of nitrogen as a side dressing. Best results can be expected if this is done before the plants are too large (about 6 inches tall). There is some indication that nitrogen applied too near time of tuber set results in accelerated vine growth at the expense of tuber set and growth.

Lime and sulfur

Sulfur and lime seldom limit yields because of a deficiency of these elements in the soil. They are of primary importance in their effect upon the soil pH that influences scab and yield.

High yields of clean potatoes can be obtained on a suitable soil with a pH range between 4.8 and 5.4.

When pH is above 5.4, scab can be a problem and sulfur is used to bring the pH down. The use of about 100 pounds of sulfur per ton of fertilizer has been helpful under conditions of light scab infestation. With severe scab infestation it may be advisable to use scab-resistant varieties (page 16). Broadcast applications of from 300 to 600 pounds of sulfur, depending upon the severity of scab, is sometimes advisable. Heavy applications of sulfur may reduce potato yields. The use of sulfur on muck soils is of questionable value since large quantities are required to affect pH.

When the soil pH is below 4.8, yields of potatoes may be reduced because of the presence of toxic quantities of aluminum and other elements. Applications of lime tend to render these elements less available, therefore non-toxic.

On farms where potatoes are planted in rotation with other crops,

it is advisable to make lime applications a year or so in advance of the potato crop.

Soils that border on the too acid side should be checked for pH every year or so and limed accordingly.

Fertilizer placement

Fertilizer which is to be banded through the planter is placed in two bands, one on each side of the seed. The bands are usually from ½ to 2 inches below the seed, with about 2 inches of soil between the fertilizer and the seed piece. Fertilizer should never be placed directly above or below the seed piece nor mixed with the soil around the seed piece. These practices delay emergence and reduce stand.

On upstate mineral soils, one-half of the mixed fertilizers, applied at the recommended rates, is applied broadcast before plowing and one-half through the planter in bands at planting time. Yield increases have been observed where this practice is followed.

On Long Island, all mixed fertilizers are applied in bands at planting time.

On muck soils, either banding at planting time or broadcasting before plowing has been equally effective.

Planting

Time

The time to plant potatoes varies considerably from one section of the State to another, beginning about mid-March on Long Island and ending in early June in upstate New York. In general, potatoes should be planted as early as possible after the soil has begun to warm up and is dry enough to work. Planting too early in a cold, wet soil often results in seed decay and poor stands.

Depth of planting

Seed are usually planted from 3 to 4 inches below the soil surface. Planting deeper, especially in heavy soil, results in delayed emergence and often in reduced stands from seed-piece decay.

Since soil temperature has a marked influence on the rate of growth and emergence of sprouts, it is recommended that the planter discs be so adjusted that seed are covered with from 1½ to 2 inches of soil.

This shallow cover permits the soil surrounding the seed piece to warm up quicker, favoring early comeup. Fertilizer materials should never be placed in contact with the seed (page 26).

Rate of planting

Row width is usually 34 inches, although some growers use a 32- or 36-inch row.

Spacing of seed within the row depends primarily on variety and purpose for which potatoes are grown.

Some of the newer varieties, such as Kennebec, set few tubers per plant and should be spaced closer together to prevent production of too many oversize potatoes.

Table-stock growers usually space seed pieces from 10 to 12 inches within the row; whereas seed growers who are interested in getting a higher proportion of small tubers, space seed from 6 to 9 inches.

Table 1. Bushels of seed required to plant an acre

Row width	Distance between seed in row	Weight of seed pieces (ounces)		
		1	1½	1¾
Inches	*Inches*	*Bushels*		
32	6	34.0	51.0	59.6
	8	25.5	38.3	44.7
	10	20.4	30.6	35.7
	12	17.0	25.5	29.8
34	6	32.0	48.0	56.0
	8	24.0	36.0	42.0
	10	19.2	28.8	33.6
	12	16.0	24.0	28.0
36	6	30.2	45.4	53.0
	8	22.7	34.0	39.7
	10	18.2	27.2	31.8
	12	15.1	22.7	26.5

Potato planters

Proper planting is important in the successful growing of a potato crop. The planter must be able to place the seed piece at the proper depth in the soil and equally spaced at regular intervals. It should also be possible to adjust the planter so the fertilizer can be applied at a uniform rate and so placed that it will not injure the seed piece but will provide the best possible conditions for supplying plant foods. To do this, the planter must be properly cared for, correctly adjusted and operated. There are two types of automatic picker planters: (1) the picker wheel type and (2) the picker arm type. The picker wheel type is the most common.

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Picker-wheel planters

One of the best ways to examine a planter is to place blocks under the axle high enough to raise the wheels off the ground about as high as the seed is to be planted, and then to turn the wheels and observe the operating parts. The condition and adjustment of the picker wheel are important in determining the accuracy with which the planter delivers the seed pieces. All broken or bent picks should be replaced and the lock screws that hold the picks securely tightened. The cam actuating the moveable arm which holds the picks should be adjusted so that the picks are completely withdrawn from the seed piece. If this is not possible, a new cam and arm may be needed. If there is considerable end play and looseness in the hub of the picker wheel, it should be remedied by replacing with new parts. The disc openers on the planter should be set to open a deep furrow, and the fertilizer tube should be adjusted so as to be directly behind the disc openers. The covering discs should be set wide apart and slightly farther apart on the bottom than on the top. This gives the desired shallow coverage of the seed and leaves the fertilizer bands undisturbed.

At the end of the season, the fertilizer-feeding mechanism should be taken apart and thoroughly cleaned and all metal parts covered with oil. When the planter is to be used, it should be cleaned again and checked to see that all parts move freely and the throat opening gates are free. The rate at which the fertilizer is fed can be regulated by changing the speed of the feeding device or by changing the size of throat opening or by both. Usually, it is more desirable to run the fertilizer as slow as possible and still obtain the desired distribution. A large drive sprocket and a wide throat opening are best.

All working parts must be greased and kept greased. Lubrication is cheaper than new repairs or a new machine.

Weed Control and Cultivation

CULTIVATION should be primarily for the control of weeds. In some rather heavy soils it may be necessary to cultivate to increase aeration and in some soils it may be profitable to break any crust formed by heavy rains so that moisture may be more rapidly absorbed.

A weeder or spike-tooth harrow with the teeth set as flat as possible are best to control weeds before the plants emerge and while the potatoes are still rather small. Row cultivation, using cultivators with various types of teeth, shovels, or disks, usually follows when the plants are larger. Two or three cultivations and one hilling are quite common. Primarily to prevent greening of tubers, it is much more necessary to

hill such variety as Katahdin than varieties which do not set tubers so shallow.

Deep cultivation after plants emerge or high hilling late in the season injures many roots and is likely to reduce yields. In hilling, wide shallow sweeps should be used to gather soil from the entire area between the rows. Hills should be wide and as shallow as possible. The main purpose of the hill is to cover and kill the weeds in the row and to prevent shallow-set tubers from being exposed to light. Hilled soils dry out excessively as compared with more nearly level culture.

It is well to do only as much cultivation as is needed to control weeds and to protect shallow-set tubers. The more cultivation, the greater the compaction of soil from the tractor wheels and the greater the injury to the physical condition of the soil and to the potato roots.

The control of weeds in potatoes with chemicals is one of the biggest labor-saving procedures since the advent of mechanized potato growing. Results of experiments on mineral soils in upstate New York during the past seven years show that annual weeds can be adequately controlled in potatoes with one pre-emergence application of chemicals if grasses are not too troublesome.

Some of the advantages of chemical weed control over cultivation are (1) that considerably less labor is needed, (2) the chemical controls weeds even when the soil is too wet to cultivate, (3) there is no root injury, and (4) there is considerably less compaction of soil from tractor wheels.

In most potato fields one man, a tractor, and a 10- or 12-row sprayer can apply chemicals to an acre in about 5 minutes. This operation is necessary only once for weed control followed late in the season by one cultivation or hilling. On the other hand, with a 2-row cultivator moving at one-half the speed of the sprayer, it would take a man, tractor, and cultivator one hour to cultivate the same acre of potatoes. Cultivation and hilling is necessary in most fields three or four times each season to control weeds adequately.

Recommendations for chemical weed control on mineral soils in upstate New York are as follows: Approximately two weeks after planting and before the potatoes emerge, apply any one of the following chemicals:

1. Sinox General, Dow General, or some similar dinitro compound, 3 pints plus 10 gallons of diesel oil made up with water to 50 to 100 gallons and applied uniformly to each acre of potatoes.
2. Sodium pentachlorophenate, 10 pounds and 10 gallons of diesel oil made up to 50 to 100 gallons with water, and applied to each acre.

3. Premerge, Sinox PE, or some similar dinitro compound, 1 gallon to 50 gallons of water and applied to each acre.

These materials may be applied with the present potato sprayer. Several rinsings with water before using the sprayer for insect and disease control are adequate. The brush type of boom with fan-type nozzles is preferred to others.

Later this chemical treatment can be followed if desirable or necessary by one cultivation or hilling to prevent greening of any exposed tubers near the surface and to cover any weeds that have appeared in the rows. These procedures in most instances have resulted in clean fields of potatoes with yields equal to those of normal cultivation.

Control of Insects and Blight on Foliage

THE Colorado potato beetle, the flea beetle, the potato aphid, and the green peach aphid are the chief pests of potato foliage. Both early and late blight can be harmful in some seasons.

Potato beetles and their slugs chew the leaves of young plants and if unchecked they can destroy the plants. Both stages are readily killed by DDT, calcium arsenate, or rotenone.

Flea beetles are tiny black insects that chew pinholes in the leaves. They appear as the plants break the ground. A second brood appears in August. The immature or larval stage is a small slender white worm that feeds on potato roots and tubers, and may burrow into the tubers in early September. The injury may be serious enough to throw the potatoes out of grade. DDT controls flea beetles readily.

In some seasons the **pink and green potato aphid** and the **green peach aphid** develop in enormous numbers on the foliage. The potato aphid feeds on the underside of the leaves and also clusters on the terminals. The aphids may suck the sap to the point where the crop yield is cut materially.

Green peach aphids feed largely on the underside of the lower leaves. This aphid is of special importance to the grower of seed potatoes because it can transmit virus diseases such as leaf roll from plant to plant.

Both kinds of aphids can be controlled with parathion or TEPP. Nicotine sulfate is somewhat effective against aphids.

Two forms of **blight** can be harmful to potato foliage. Early blight may appear as small spots containing concentric rings on the leaves. When many spots are present the plants can be harmed and the yield reduced. Late blight develops when the temperatures are cool and the plants are moist with dew or rain followed by some hours of warm

weather and high humidity. This disease can spread rapidly in wet periods. It can cause an early death of the plants and a rotting of the tubers when the spores are washed from the leaves or stems to the potatoes in the ground. Potatoes affected by late blight will rot in storage even though the trouble may not be noticeable at harvest time. Blight is discussed further on pages 35 and 36.

Both kinds of blight can be controlled by sprays or dusts when insecticides are applied to control potato-foliage insects. The fungicides used as sprays for blight control are bordeaux mixture, some copper compounds, and carbamates. Dusts that control blight are copper-lime and the carbamate dusts. Especially when late blight appears, thorough treatments must be made at five- to seven-day intervals to get good control. A regular schedule should be maintained until the plants die normally or are destroyed by mechanical or chemical means (page 54).

Insect and disease control schedule

On Long Island

Early maturing potatoes, such as the Cobbler and Katahdin, need from three to five sprays or about seven dust treatments to control insects and prevent blight. Late-maturing varieties, such as Green Mountain, need seven to ten applications. In blight seasons on the South Fork as many as twelve treatments may be necessary.

For sprays, 2 pounds of wettable powder of DDT, or 1 quart of 25 per cent DDT emulsion, to 100 gallons of bordeaux mixture of the 8–4–100 formula is recommended. A 10–5–100 formula should be used during the latter part of the season or when blight becomes imminent. A carbamate at manufacturers' directions can be substituted for the bordeaux mixture but it must be applied every five days to give adequate protection against late blight. From 100 to 125 gallons of spray need to be applied per acre at 400 pounds pressure. The larger amounts are necessary on well-grown vines.

As dusts a material containing 5 per cent DDT and 7 per cent metallic copper is recommended at the rate of 35 to 40 pounds per acre. These dusts are used commonly on muck-grown potatoes or where a water supply is not adequate. It is usually advisable to make more treatments when dusts rather than sprays are used to control insects and the blights. The dusts are applied preferably when the plants are wet and when there is no wind.

There was evidence on Long Island in the late summer of 1952 and again in 1953 that DDT was not controlling the potato beetle and its slugs. They had shown resistance to DDT. This was also true in part in 1953 for flea beetles. Field tests in 1952 showed that rotenone extract

(1 quart of 5 per cent to 100 gallons of water) or parathion either wettable powder or the emulsion, or methoxychlor, or dilan satisfactorily controlled potato-beetle slugs. It is not known at this writing which insecticides besides rotenone will control flea beetles. Since some potato beetles and flea beetles are affected by DDT, and since it is felt that DDT may provide a stimulating effect on plant growth, it appears that the grower should continue to use DDT along with another more effective insecticide, at least when insects are present or likely to be present on the vines.

DDT is not likely to give satisfactory control of aphids in seasons when these insects are abundant. At such times 1 pound of 15 per cent wettable powder of parathion or 1 pint of 25 per cent parathion emulsion is used in the sprays as a substitute for the DDT. TEPP at manufacturers' directions is also a good aphid killer but has little or no residual effect. Parathion has killing power for from five to seven days after application. Both parathion and TEPP also give good kills of the potato beetle and flea beetles.

Growers of seed potatoes should use an aphicide like parathion more often than growers of table-stock potatoes. It is a good practice for seed growers to use an aphicide along with DDT or in place of DDT in every other spray application beginning when aphids first appear.

Aphids can also be controlled by dusts. These are a 1 per cent dust of parathion or a 1 per cent dust of TEPP. If a TEPP dust is used, it should be freshly mixed. Either is applied at the rate of about 35 pounds per acre.

Another good killer of potato aphids is malathon. It can be used either as a dust or as an emulsion and wettable powder in a spray form. It is a phosphate type of chemical but not nearly so toxic to the user as are parathion and TEPP. It should be used at manufacturer's directions.

Parathion and TEPP are highly poisonous insecticides. They must be used only with great care. All the precautions given by the manufacturer on the labels must be followed strictly.

In Up-state

A later and somewhat longer growing season requires more treatments for up-state grown potatoes than for Long Island grown potatoes. Early maturing varieties grown on muck soils may need only from five to seven treatments to control insects and diseases. On late-planted and late-maturing varieties, from eight to twelve sprays or dusts may be necessary. They must be made very thoroughly, especially in periods when late blight is present.

Other Diseases and Their Control

MANY diseases of potatoes are of economic importance. A progressive grower cannot afford to overlook this aspect in the production of a profitable crop and should be able to recognize and control the common potato diseases that may attack his crop.

Parasitic Diseases

Ring rot

Ring rot is a bacterial disease caused by *Corynebacterium sepedonicum*. The vine symptoms generally appear during the latter part of the growing season, usually after the potatoes have blossomed. Only one or two stems in a hill may display the symptoms, while the remainder of the plant appears healthy. The lower leaves first show a wilting accompanied by an upward rolling of the margins. An interveinal yellowing of the leaves is followed by the development of dead areas extending from the margins inward. There is the eventual death of the leaf, the stem, and sometimes the entire vine. There are no external stem symptoms. In slight infections, the plants may not show distinguishable symptoms.

Tubers produced by affected plants usually are infected. The bacteria may also enter tuber wounds by contacting contaminated cutting knives, planters, crates, storage bins, and other exposed surfaces. Generally, in the early stage, external symptoms are not observed, so the stem end must be cut to detect the disease. The vascular ring of the diseased tuber is discolored; it is lemon-yellow to light brown. The vascular tissue is soft and cheesey in texture. If the tuber is squeezed, a yellow exudate is forced out of the tissue and into small piles on the cut surface (figure 5). Laboratory examination of the ooze will positively identify the causative organism. As the disease progresses, the rotting of the vascular and surrounding tissues becomes more pronounced. Irregular cracking of the surface may appear in areas where there has been reddish discoloration of the skin. A soft rot may develop in the center of the tuber because of the invasion of other organisms so only a shell is left or the tuber may be completely decayed.

Figure 5. Bacterial ring rot

Control

Refer to *Sanitation and Disease Control* (page 11).

Blackleg

Blackleg is a bacterial disease caused by *Erwinia atroseptica*. When warm, moist conditions prevail, there may be a considerable loss due to this disease.

The foliage of infected plants is compact and erect due to the upward rolling of the leaves. This condition is accompanied by a yellowing of the foliage. As the disease progresses, the base of the stalk develops light brown to black rotted areas. These areas or lesions may be wholly underground, or they may extend several inches above ground. The rotting often continues until the stalks fall over onto the ground. When drier conditions prevail, many stalks show only a blackening of the center or pith, and this discoloration may extend to the top of the plant. Often there are thickened stems and aerial tubers in the axils of the leaves.

The tubers become infected when the disease progresses through the stolons to the developing tubers. The presence of the bacteria in a tuber is not always evident. The stem end of infected tubers usually develops exterior and interior darkened areas, and an interior soft rot. The rotted portion continues to enlarge or dries to become firm and shrunken. The rot may continue in storage. It has been shown that the seed-corn maggot is capable of disseminating the bacteria, especially to seed pieces.

Control

Since the bacteria are carried over in tubers produced by infected plants, only certified seed or seed from non-infected plants should be planted. It is preferable to plant whole seed, but, if cut seed is planted, it should be corked properly before planting. Proper temperatures and the avoidance of wet conditions in storage will reduce the amount of rot.

Common scab

Common scab is caused by *Streptomyces scabies*. The disease generally is found in most potato-growing areas. Reduced marketability is the primary loss due to this disease.

The tubers are the only plant parts which exhibit the disease. The pathogen enters the tubers through cracks and lenticels in the skin. Raised corky spots or areas may be so numerous and extensive as to cover most of the tuber surface (figure 6). The scabby spots may produce a pitted condition; however, they usually do not penetrate the tuber more than 1/16 to 1/8 inch. There may be a russeted appearance due to the cracking of slightly raised areas. Common scab does not cause a rotting or decaying of the tuber tissue.

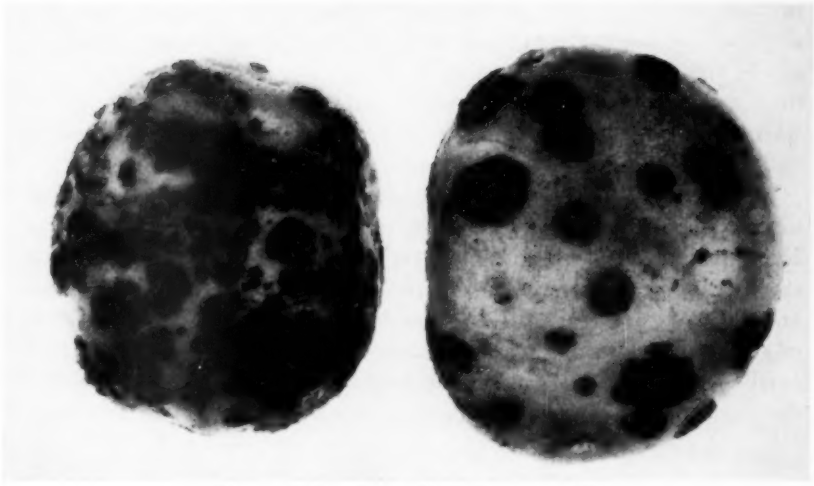

Figure 6. Common scab on potato tuber

The causative organism is capable of persisting from year to year in the scabby spots on the tubers. It also lives successfully as a saprophyte in the soil, making control through rotation difficult. Other root crops may be attacked in a similar manner. The activity of the organism is affected by weather and soil conditions. Alkaline soils are conducive for the growth of the organism, while acid soils tend to reduce it. A few species are capable of growing in soils with a pH less than 5.0 or greater than 7.8. Drier soil conditions also tend to increase the severity of the disease.

Control

Refer to *Common Scab Control* (page 15).

Late blight

Late blight is one of the commonest and most destructive diseases, especially during wet seasons. This disease is caused by a fungus *(Phytophthora infestans).* It appears on the foliage as irregular, dark-brown to black, water-soaked areas (figure 7). These areas or spots can enlarge rapidly under proper conditions to

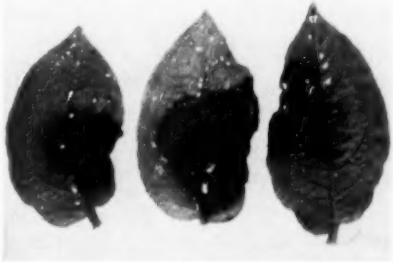

Figure 7. Potato leaflets affected with late blight

include the entire leaf or vine, and reduce it to a rotted mass. The underside of the leaf may show white mildew or mold around the margin of the darkened diseased areas. These fine white strands can produce numerous spores during warm moist weather. These spores are washed or blown to nearby plants or fields where infection can develop and kill many plants in a few days.

The disease appears on the surface of the tubers as irregular, brown or purplish-black metallic areas. Directly beneath these areas the flesh is reddish brown, extending inward only for a short distance. The causal fungus produces a dry rot, but bacterial organisms may follow and produce a soft rot. Infection of tubers takes place by the washing of the spores from the leaves or stems down through cracks in the soil to the tubers. The spores on the living foliage may reach tubers by direct contact at the time of digging, especially if the vines are wet.

Control

Late blight is initiated by the production of spores on infected shoots developing from blighted tubers. Volunteer plants should be rogued and affected tubers should not be used for seed. Discard or cull piles should be handled in the proper manner (page 11). A strict spray or dust schedule should be maintained throughout the entire season, commencing when the plants are from 4 to 6 inches high (pages 31 and 32). Potatoes should not be dug until all the vines are dead, and preferably only when the dead vines are dry.

Early blight

A fungus, *Alternaria solani,* causes the disease known as early blight, or leaf spot. Weakened plants, plus higher temperatures and adequate moisture, are conducive for the development of the disease. The disease may be so severe as to cause considerable defoliation and a reduction in yield.

The leaf is the plant part primarily attacked by the pathogen. The dark-brown to black colored lesions or spots may be round to oval or irregular and angular. The lesions usually display a target-board effect due to the production of concentric ridges on the surface of the affected areas. Often the disease is observed first on the lower or older leaves of the plant. The affected stalks or petioles also show similar necrotic areas with concentric ridges.

Lesions sometimes are produced on the tubers. These spots appear as small, slightly sunken areas with raised and slightly puckered margins. These spots also serve as entrances for secondary organisms which cause the rotting of the tuber.

The spores of the fungus are capable of overwintering and thus initiate the disease the following spring. The mycelium of the fungus also can survive the winter in affected plant parts and produce spores the following season.

Control

Refer to *Control of Insect and Blight on Foliage* (page 30).

Rhizoctonia

The rhizoctonia disease also is known as *black scurf* and *rhizoctonia canker.* The disease is caused by a fungus, the imperfect stage of which is *Rhizoctonia solani.* It may account for reduced stands as well as reduced yields from the affected plants.

Figure 8. Cankers on sprouts caused by Rhizoctonia

Young sprouts often are attacked and killed, which promotes the development of side sprouts. The sprout symptoms appear as brown, sunken cankers or spots, which can cause the girdling of the sprout or young stem so the tip or aboveground part dies (figure 8).

Cankers can develop on the stems of older plants. The cankers appear as brown, irregular streaks or areas, which do not extend very deep into the stem. Such cankers usually are found on the stem portion below the soil surface.

A slight infection probably does little harm, although the cankers may be so extensive as to girdle the stem. Some interference with the normal movement of plant-food materials can be attributed to the presence of these cankers. The aboveground vine becomes yellow to reddish-yellow, the leaves roll, and sometimes "aerial tubers" form. When the stolons are attacked, the develop-

ment of the new tubers is arrested so that they remain small.

Dark-brown to black fungus bodies are formed on the surface of the tubers, and are called *sclerotia*. These superficial sclerotia are overwintering forms which do not harm the tubers since there is no penetration. Sometimes there is a localized or general russeting of the tubers when grown in highly infested soil.

When tubers are planted, the attached or unattached sclerotia become active and produce the thin mycelial threads which invade the young sprouts, stolons, roots, stems, and tubers. The fungus reaches the soil surface about mid-season and spores are produced. The role of these spores in the dissemination and perpetuation of the fungus is not thoroughly understood. The formation of sclerotia is the primary means for the persistence and overwintering of the fungus. Unfortunately many cultivated plants and weeds are hosts for the fungus so the cycle is completed regardless of whether a potato crop is present each year. In addition, the fungus is capable of living as a saprophyte in the soil for long periods of time.

Control

There is no one effective control measure. Certain practices tend, however, to reduce the severity of the disease. Affected tubers should not be planted unless they previously have been treated. A mercurial seed treatment is effective, but a formaldehyde treatment is advisable for alkaline or scabby areas (page 22). A crop rotation of several years often materially reduces the disease incidence. The amount of disease tends to be more if seed is planted in heavy or poorly drained soils, or when the soil is cool and wet. Such conditions retard the rapid development of the plant and thus afford a better opportunity for the attack of the fungus.

Fusarium wilt

Fusarium solani f. *eumartii* and *F. oxysporum* can cause wilt of potato. These pathgenic agents are capable of killing the vines early, with a subsequent reduction in No. 1 tubers. The disease is more severe under conditions of medium soil moisture and hot weather.

The plant symptoms produced through the action of these parasites are not distinguished easily from those produced by other wilt organisms. Therefore, there is a considerable overlapping of symptoms so final diagnosis can often be made only in a laboratory.

When *F. solani* f. *eumartii* is the pathogenic agent, the first symptom is a mottling of the upper leaflets produced by a yellowing of the interveinal areas. Slight infections result in a faint mottling, while severe infections produce pronounced mottling followed by a drying

and drooping of the leaves. There is a brown discoloration of the vascular tissue first at the base of the stem and later it may extend throughout the plant. There may be brown colored areas of rotted cortical tissue at the base of the stem. The severely affected plants often show a brown flecking of the pith, particularly at the nodes. An upward rolling and purpling of the leaves, a rosetting at the vine top, and the formation of "aerial tubers" are characteristic under certain conditions. The roots later become invaded, producing a brown discoloration of the vascular tissue and finally the sloughing off of the cortical tissue.

When plants are attacked in the field by *F. oxysporum,* the first symptoms generally consist of the yellowing and drooping of the lower leaves, followed by the progressive upward movement of these symptoms on the vine. Marginal browning of the leaflets soon appears due to the drying out of the yellowed areas, and the final result may be a rosetting at the vine tip. The vascular system becomes discolored, but the discoloration often does not extend to the top of the plant. The affected roots also may be destroyed as described. Plants produced from infected tubers are generally weaker in appearance, being spindlier and lighter colored, and usually die prematurely.

Stem-end browning of the tubers is the result of an invasion of the stolons. The presence of a brown vascular discoloration of the tuber is not a specific symptom for wilt diseases, nor do all affected tubers necessarily show discoloration. Soft rotting of adjacent tissues may accompany the vascular discoloration. Vascular discoloration may continue to develop without decay following harvest and while in storage.

Control

Tubers from affected plants certainly should not be used for seed. Long rotations, at least 3 to 4 years, often prove beneficial for the reduction of disease incidence in infested fields. The removal of affected plants from the field will reduce the spread and increase of the organism. Very suspectible varieties (page 16), such as Russet Rural, should not be planted in heavily infested potato soils.

Verticillium wilt

The causal agent, *Verticillium albo-atrum,* is a widely distributed fungus, because it attacks a large number and many kinds of plants. The extent of losses due to this disease has not been estimated, but it is found to be present in some degree throughout the potato areas of the State.

The symptoms for Verticillium wilt are practically the same as those for Fusarium wilt caused by *F. oxysporum.* The early symptoms are

Figure 9. Verticillium wilt symptoms on potato leaves
Healthy *(left)*, mild *(center)*, severe *(right)*

yellowing and drooping of the lower, older leaves, plus a pronounced wilting of the foliage, particularly during dry weather. The disease proceeds upward from the base of the plant, the yellowing and browning of the leaves commencing at the tip (figure 9). There is a simultaneous rolling and curling of the leaflets, and the vines die prematurely.

The vascular tissue of the affected stems discolors, and the woody tissues become reddish brown. The vascular discoloration usually extends several inches up the stem from the base, and sometimes extends into the tip. Basal stem rot is not observed for Verticillium wilt. The tubers also display stem-end browning and vascular discoloration which may extend through to the bud or eye end. This tuber symptom appears the same for Fusarium wilt and certain physiological changes in the plants. Affected tubers often do not exhibit this discoloration, although the pathogen is present.

A tuber symptom has been observed recently which may or may not be directly associated with the Verticillium wilt disease. Eyes of some tubers from hills of affected plants are pink in color, particularly those near the bud or eye end. These superficial discolored areas may appear as distinct lesions with well-defined margins or as irregular blotches. The term "pink-eye," has been applied to this condition. These areas

apparently do not rot in storage; however, the affected eyes tend to sprout less readily in the spring.

Control

Crop rotation and seed selection offer the best methods of control. A three- to four-year rotation of potatoes with grains and legumes has been found to reduce the prevalence of the disease. All parts of affected plants should be removed from potato fields to retard both the build-up and the spread of the pathogen. The adjoining plants on either side of the wilted plant also should be removed, since they can become infected through root contact with the affected plant.

Storage and seed-piece dry rots

The dry rots are caused primarily by various species of Fusarium. The disease is prevalent in all potato areas, in some cases causing 50 per cent or more loss of stored stock and 10 per cent or more reduction in stand.

The organisms that cause this disease are present in the potato soils. The pathogens can be distributed by soil adhering to tubers, crates, sacks, or farm implements. The causal organisms enter the tubers through wounds, bruises, mechanical injuries, and cuts. Warm temperatures and adequate moisture, coupled with unhealed surfaces, favor the development of the disease.

Fusarium sambucinum f. 6 and *F. coeruleum* seem to be the most prevalent dry-rot organisms in this State. A brown area first appears on the surface which increases in size and later becomes sunken. The color

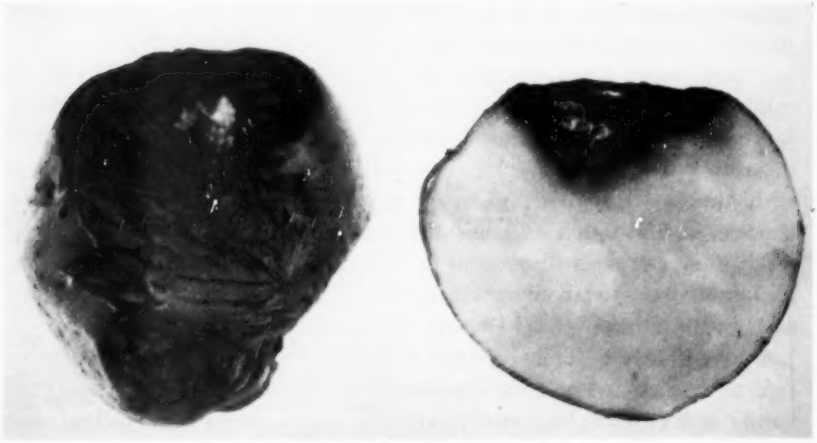

Figure 10. Fusarium dry rot

of the affected tissue below such areas ranges from light brown to black, depending upon environmental conditions. Large portions of the tuber may become involved so that the majority of the tuber is affected (figure 10). As the disease progresses, the tissue dries and the skin becomes wrinkled. The wrinkling sometimes is in the form of concentric rings. White, pink, or blue cushion-shaped tufts may appear on the surface. These tufts are composed of many mycelial threads which produce numerous spores. The tuber finally becomes dry and hard. The cut surface of infected seed pieces may not always demonstrate symptoms, since they may be noticeable only in the discolored tissue below the surface. In other cases, the production of spores is observed on these surfaces.

Control

Extreme care should be taken at harvest time to prevent wounds, bruises, mechanical injuries, and abrasions of the tubers. The tubers should be stored at a low temperature and a moderate relative humidity, with good ventilation (page 59). The storage houses should be thoroughly cleaned and disinfected prior to storing the potatoes. Seed-piece rot can be reduced by employing a seed treatment (page 21). Planting whole tubers or providing conditions favorable for rapid healing of the cut surface also helps to reduce the amount of decay.

Leaf roll

Leaf roll is a virus disease that causes considerable losses in many potato-growing areas of this State. There is a decided reduction in yield (50 to 60 per cent or more) when leaf roll is present. The leaf-roll virus is transmitted from diseased to healthy plants by aphids; the primary vector or carrier is the green peach aphid *(Myzus persicae).*

Plants grown from infected seed are stunted and lighter green in color than those from healthy tubers. The stalks are shorter and there is a pronounced rigidity and uprightness of the leaves. The leaflets show an upward rolling and inward curling of the edges, commencing with the lower leaves and progressing to the tip. The leaflets are leathery to the touch and feel thicker than normal. Often there is a reddish or purplish discoloration along the margins and tips of the leaflets, in varieties containing a red or purple pigment. These symptoms generally are referred to as *secondary leaf roll.*

When plants become infected following a current season inoculation by aphids, no striking symptoms may be observed. If the plant is young and growing vigorously, only the upper leaves show rolling and some color differences. This is referred to as *primary leaf roll.* If infec-

tion is later in the season, symptoms usually are not discernible. When tubers from such plants are used as seed, the produced plants display the characteristic *secondary leaf roll* symptoms described. A net necrosis sometimes is produced in certain varieties, such as Cobbler and Green Mountain. The necrosis appears as a fine network of brown-colored phloem tissue. The discolored netting may extend throughout a portion or all of the tuber. This net necrosis is found only following "primary leaf roll" and never in tubers from "secondary leaf roll" plants. There are no external differences to be noted between infected and non-infected tubers.

Control

Certified seed or other seed free of the disease should be planted. Volunteer plants should be removed and destroyed. Seed-stock growers are referred to methods described under *Foliage Insect and Disease Control* and *Certified Seed Production* (pages 30 and 70).

Spindle tuber

Spindle tuber is a virus disease that causes a loss in the yield and the marketability of the stock. Although the disease is not prevalent in this State, it always has the potentiality of becoming a disease of primary concern.

Weaker and smaller plants usually are produced by affected tubers. The affected plants also show an erect and spindly type of growth. The foliage of infected plants may be darker green color and exhibit a duller reflection of light when compared with foliage of healthy plants. The leaves assume a more acute or sharp angle in relation to the stem, so the leaves are pulled together. The margins of the leaflets may be fluted so as to have an uneven and upward-turned appearance (figure 11). These vine symptoms are difficult to detect. An early season infection may result in the development of symptoms only toward the top of the plant. The symptoms are more distinct under conditions of high temperatures and adequate soil moisture than

Figure 11. Sebago potato plant showing symptoms of spindle tuber

under low temperatures and lack of soil moisture.

The tubers produced by affected plants usually are elongated and may be somewhat pointed at one or both ends. The number of eyes may be increased materially and accompanied by the production of prominent "eyebrows." The tubers of red varieties become lighter in color in areas or entirety. Affected tubers may have a normal appearance if produced by plants that have become infected during the current season. Giant hills also may form spindle-shaped tubers so that tuber diagnosis is not always possible. Grasshoppers, aphids, leaf hoppers, flea beetles, and tarnished plant bugs are capable of transmitting the virus. The cutting knife can transmit the virus, and tubers may become inoculated through the rubbing of affected sprouts.

Control

Certified (page 70) or disease-free seed only should be planted. Since diseased tubers are not always recognizable, as an added precaution the cutting knife can be dipped in alcohol and flamed following the cutting of each tuber; or whole tubers can be planted. Seed stock growers must use satisfactory roguing practices and insect control measures.

Yellow dwarf

The virus disease, yellow dwarf, has been reduced in its importance in New York State during the past several years. Losses in yield of 20 per cent or more due to this disease have been recorded. The virus may attack several plants other than potatoes, but it generally does not produce such marked effects.

Plants produced from infected seed pieces may be severely dwarfed so that they attain a height of only a few inches. Many shoots never reach the surface, particularly if warm soil conditions prevail. The characteristic vine symptoms usually commence at the tip and progress downward. The leaflets become yellow and rolled, often accompanied by rosetting. The pith and cortex of the affected stalks are characterized by small rusty-colored necrotic spots. The necrosis may extend the entire length of the stalk and is especially prominent at the nodes. The acutely affected plants generally die early in the growing season. Symptoms of current-season inoculation may be less severe, showing only mild forms of chlorosis, stem necrosis, and leaf roll. Cool weather has a tendency to mask the vine symptoms. In some instances only single shoots display the symptoms while the remainder appear healthy.

Usually the tubers are misshapen when produced by severely affected plants and show few or many rusty-colored or brown specks dispersed throughout the inner tissue, especially near the middle of the tuber.

The development of growth cracks is common; but it is not a good diagnostic character, since there are other causes of such cracks. Mildly or partially affected plants may produce normal appearing tubers which may be infected and serve as a source of inoculum if used for seed. The tuber necrosis has not been observed to increase during storage.

Two strains of the virus have been determined and each is capable of causing the disease. The virus is transmitted by the clover leafhopper, one strain by *Aceratagallia sanguinolenta* and the other strain by *Agallia constricta*. The virus overwinters in the insect under certain conditions, or more commonly in plants other than potatoes. The varieties Sebago, Warba, Houma, and Katahdin have shown a tendency toward resistance.

Control

Certified (page 70) or disease-free seed should be used. The seed plot should not be near waste land in which wild daisies are growing. Insect-control methods (pages 31 and 32) will help to prevent the spread of the disease. The testing of seed samples will help to ascertain the amount of infected tubers (page 71).

Mosaics

The mosaic diseases are caused by viruses. Latent mosaic, mild mosaic, and rugose mosaic are recognizable in the potato areas of New York State.

Latent mosaic is common for all of the older commercial American varieties, but is less prevalent in newer varieties. The infected plants may appear healthy since they act as symptomless carriers of the virus. The disease is caused by the X-virus, of which there are several strains. These strains can be differentiated by characteristic symptoms when transmitted to other host plants. The virus is transmitted through the rubbing of leaves rather than by insects. A reduction in yield of 10 to 20 per cent results when the virus is present.

Mild mosaic is caused by potato virus A, alone or in combination with the X-virus. Warm temperatures tend to suppress the expression of symptoms while cool temperatures support them. The mottling is attributable to the production of light-green or yellow areas alternating with normal green areas that have undifferentiated margins. Severely affected plants show a pronounced mottling and crinkling or wrinkling of the leaves. The plants often have a droopy appearance and die prematurely. The infected tubers do not possess any distinctive symptoms. Several species of aphids transmit the virus.

Rugose mosaic is a disease caused by potato virus Y, usually in combination with the X-virus. The leaves of affected plants are wrinkled

Figure 12. A normal plant (left) and a plant affected by rugose mosaic (right)

or rugose, while the mottling, if present, usually is not so definite (figure 12). Thin necrotic streaks may be present on the stems and petioles, while the lower petioles and leaves become brittle. The plants may be stunted and die prematurely. Current-season infection symptoms include necrotic areas of the leaves, petioles, stems, and vein discoloration. Current-season infection symptoms may appear first only on one shoot. The infected tubers do not show any symptoms. Aphids act as vectors for the virus.

Control

Table-stock growers should plant certified seed or seed relatively free of the disease. Seed growers should follow the methods outlined under *Certified Seed Production* (page 70).

Golden nematode

The golden nematode *(Heterodera rostochiensis)* was first found on Long Island in 1941.

The vine symptoms are not distinct. Several affected plants generally are observed in an area or spot in the infested field. These plants usually are stunted and poorly developed. The affected plants may be wilted and die prematurely. If the plants are carefully removed from the soil, the tiny white to golden brown colored cysts sometimes may be seen attached to the surface of the root (figure 13). These cysts are easily detached from the root and they are about the size of the head of a small pin.

The resistant cysts are the egg-containing bodies of the female. They are capable of hatching viable young larvae even after persisting in the soil for as long as 17 years. The larvae hatch from the eggs held within the cysts during the spring when proper conditions prevail. The larvae enter the roots and derive their nourishment from the vascular tissue. The larvae pass through various stages of development until the females produce eggs and later die to be transformed into cysts. The vine growth and tuber development are reduced by the invasion of the roots by numerous larvae which reduce the vitality of the host.

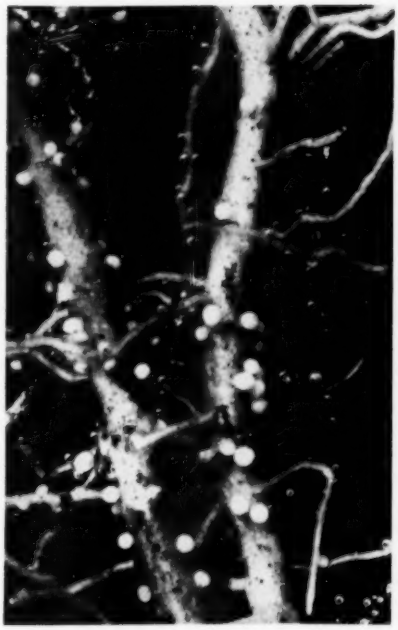

Figure 13. Golden nematode cysts attached to potato roots

Control

(see Sanitation for Disease Control, page 12).

Non-parasitic Diseases

Hollow heart

The presence of hollow heart can be detected only by cutting the tuber to expose the internal cavity or cavities which usually are near the center. The tissue immediately surrounding the cavity may be light to dark brown in color; but decaying of the tissue is not normally associated with hollow heart. Smaller as well as oversized tubers may show this condition, although it is more prevalent in oversized tubers.

Hollow heart often occurs during seasons of irregular growing conditions. When possible, uniform growing conditions should be provided throughout the season. The plants should be spaced to reduce the number of oversized tubers.

Growth cracks

Growth cracks usually extend along the bud-stem end axis of the tuber. Often they are near the bud end of the tuber. The size and extent of the cracks are variable. The cracks heal rapidly by producing

a corky layer which prevents the entrance of rot organisms and the loss of moisture.

Growth cracks may be the result of unfavorable changes in the soil and of weather conditions. The cracks also may be a varietal characteristic or a symptom expression of a virus disease, such as yellow dwarf. The exact environmental conditions that are most conducive to cracking have not been determined. The cracks are, however, believed to be due to a stress created by an uneven growth of the tuber.

Control

Cultural practices that afford more uniform growing conditions should be employed. Certified or disease-free seed should be planted.

Sunburn and sunscald

Sunburn of tubers is caused by long exposures to natural light and is often referred to as *greening*. The exposed tuber is light to dark green in color on the surface and the internal tissue has a yellowish cast. This condition produces a bitter flavor and the potato may be poisonous to certain individuals.

Sunscald is the result of direct exposure to the sun during hot weather. The exposed tissue is killed and soon becomes watery and turns brown. The affected areas generally are invaded by secondary rot organisms. In some instances the affected tissue dries so that it appears chalky or becomes leathery and hard.

Control

Proper hilling and depth of planting alleviate the occurrence of sunburn or greening in the field. Correct spacing prevents the formation of numerous large tubers which may become exposed to high temperatures. Potatoes should be removed within an hour after digging if temperatures above 85° F. prevail. If warm temperatures prevail, harvesting should be done only during the morning and the late afternoon. Restricting the use of electric lights helps to prevent greening in the storage and warehouse.

Black heart

Black heart is a tuber disease which is a result of high temperatures and a lack of enough oxygen. The center portion of the tuber usually is affected, appearing as one irregularly outlined area or as scattered areas throughout the tuber. The areas may extend to the exterior. The affected tissue varies from dark gray to purple-black in color and is sharply contrasted to the healthy tissue by definite demarcation. The tissue easily is invaded by secondary organisms, so that a soft rot soon

develops and there is a complete breakdown of the tuber. If, however, the affected tissue dries, it may become leathery and tough, followed by the production of cavities.

Control

Storage and transit temperatures should be maintained below 95° F., with an adequate oxygen supply. Tubers should not be stacked more than 6 feet high in solid piles in storage (page 61).

Secondary-tuber formation

Sprout tubers, blind tubers, or potatoes without tops are synonymous terms for secondary-tuber formation. A poor stand may result from the production of small new tubers on the seed piece or at the end of short sprouts without the presence of vine growth. This condition also may appear while they are still in storage. The rest period must be completed before secondary-tuber formation commences.

Storage conditions that favor early sprouting are conducive for the production of secondary tubers. The condition is enhanced if such tubers are planted in cold dry soils. An excessive removal of sprouts may cause the formation of secondary tubers even when the seed pieces are planted in warm moist soils.

Control

Cool storage conditions should be maintained to reduce the amount of early sprouting (page 62). Seed should not be planted before the rest period has been completed nor during unfavorable growing conditions.

Frost necrosis

Frost or freezing necrosis is caused by the formation of ice crystals in the spaces between the cells of the tuber. The symptoms of frost necrosis are varied and depend upon the conditions under which injury occurs.

In some instances external tuber symptoms are evident after thawing. These symptoms include moist surfaces and a softening and collapsing of the tissues. The interior tissues are watery and change from a normal to a black color upon exposure to air. The entire tuber or only a portion may be affected (figure 14). The tuber may shrivel and become dry, tough, and granular, or other organisms may invade the affected tissue and reduce the tuber to a slimy mass.

Various types of internal symptoms may be observed when the tuber is cut, even though no external symptoms are present. A net necrosis often is produced. Discolored streaks are formed in the vascular ring and often extend in all directions throughout the tuber as a fine net-

Figure 14. Potato tubers showing freezing injury

work. A ring necrosis or discoloration may be revealed when the tuber is cut. The vascular ring and the immediately surrounding tissues may be blackened in total or in part. Another internal symptom appears as large or small blotches. These areas appear at random within the tuber, and are gray to black in color.

Tubers freeze at or below 29.6° F. The condition of the tuber determines the formation of ice crystals at the low temperature for a period of time. Tubers subjected to low temperatures above the freezing point sweeten. Severely injured tubers should not be used as seed since they usually rot soon after planting. Mildly affected tubers can produce good vines, although their initial growth is retarded.

Control

Storage and transit conditions should be controlled to prevent a temperature drop below 32° F. (page 62). Potatoes should be harvested before the normal low seasonal temperatures appear.

Irrigation

IRRIGATION is a form of yield and quality insurance that can be obtained in no other way. To check the potato yield increases that might be expected from irrigation in upstate New York, 17 cooperative test plots were set up in 12 counties from 1949 through 1952. In 6 of the 17 tests, the yield increases exceeded 100 bushels of No. 1 potatoes per acre, in 5 others the increases were between 50 and 100 bushels, and in the remaining 6, the increases were less than 50 bushels. In

those same tests there was an increase of from 7 to 25 per cent in the numbers of tubers set on the irrigated plots. Irrigation when needed during the tuber-set or blossom period increased the yield by increasing the number of tubers set. When it was needed only during the latter part of the season, irrigation increased the size of each tuber rather than increasing the number set.

More than a thousand farmers in New York State are now irrigating over 20,000 acres of potatoes and other crops. Approximately one-half of the irrigation systems are in upstate New York and one-half on Long Island.

Water sources

A water-bearing gravel under Long Island makes it possible for any farmer to get an adequate supply of irrigation water for the cost of drilling a deep well plus the cost of the irrigation system. In upstate New York, only a limited number of valley bottoms are underlaid with a water-bearing gravel, so other sources must be used. Wells drilled into bed rock seldom furnish enough water for irrigation. Streams, farm ponds, drainage ditches, and lakes are excellent sources of irrigation water if the supply is adequate and is not polluted with industrial waste. Since New York State laws on surface water rights are not well defined, it is advisable to investigate such sources carefully before investing in an irrigation system. Where stream flow is used, new irrigators upstream may seriously reduce the water supply available to downstream irrigators. Small streams are likely to be either inadequate or unreliable. Farm ponds, if well planned and of adequate size, are one of the most reliable sources of irrigation water. The runoff in winter and early spring from any area of land in New York State is usually greater than the summer need for water on that same land. Therefore, if there are conveniently located areas of poorly drained soil on the farm, farm ponds may be the best way to solve the water supply problem.

The New York State law requires that plans and specifications for any farm pond be submitted to the State Department of Public Works at Albany before construction is started if the pond is designed to hold more than 1,000,000 gallons of water or if the drainage area above the pond exceeds 1 square mile, or if the dyke around the pond exceeds 10 feet in height at any point. This is not only a legal requirement, but also would give the pond owner legal protection in case a future flood should take out the dam and cause damage to property downstream. Any irrigation pond that is not spring-fed probably should be larger than the million-gallon limit if it is to provide water to irrigate more than 5 or 6 acres.

In figuring pond size, approximately 2 feet of depth should be allowed for evaporation and other losses. Therefore, a deep pond with a small surface area, unless it involves expensive construction features, is more efficient than a large, shallow pond of the same capacity.

Need for water

Irrigation in humid regions, such as New York State, is likely to be highly profitable some years but may not be needed every year. A knowledge of the water-holding capacity of each field and of the frequency of rainless periods of various lengths is one way to estimate the likelihood that irrigation may be profitable. The water-holding capacity of the soil depends on its type and depth. Sandy soils hold only approximately 3/4 inch of available water to each foot of depth, and loams hold about 2 inches, or an inch of water will replace the available supply in a sandy soil to a depth of approximately 16 inches and in a loam to 6 inches. Potatoes usually are a shallow-rooted crop and in some soils their roots may be limited to little more than the plow depth. The best way to find how deep crop roots penetrate in various soils is to do some digging when those crops are at their prime.

After the approximate water-holding capacities of the various fields have been determined, the probable need for irrigation can be determined by checking the rainfall records of a nearby weather observation station. During hot, dry weather crops use from 0.15 to 0.20 inches of water daily. These figures, divided into the water-holding capacity of the soil, give the approximate number of days after a soaking rain before more water is needed.

Experiments at Ithaca and on Long Island indicate that potatoes should be irrigated when the soil moisture content in the root zone gets down to approximately 50 per cent of the available supply. If one has only enough equipment to cover the area to be irrigated once every seven days, then irrigation should be started even before the soil moisture gets down to the 50 per cent level, or some of the crops may suffer seriously before they get any water. Also a glance at the weather records show that the longer one waits after one rain before starting to irrigate, the greater the chances are of putting the water on just ahead of the next rain. Only enough water should be applied to fill the soil in the root zone up to field capacity, since an excess is likely to cause leaching of the fertilizer nutrients, especially the nitrogen. Excessive irrigation can do further harm if it is followed closely by a heavy rain.

Soluble fertilizers can be applied to any crop through the irrigation system. This is usually done by adding a valve and a small suction hose

on the intake side of the pump to take the fertilizer solution from a barrel standing by the pump.

Irrigation equipment

Modern pumps and seamless aluminum tubing with quick couplers have made irrigation easier and less costly than ever before. The investment is still high, however, and a grower planning to install an irrigation system should examine carefully all of the facts involved and get competent advice. It is wise to study carefully such items as water supply, costs (both initial investment and operating costs), probable gains from irrigation, and the like.

One should first ask such questions as – "Do I have an adequate and dependable water supply for the area that I will be irrigating? Is it convenient to the fields? How will this change or interfere with my present farming operations? How much additional labor will be required? What is a satisfactorily designed system for my farm? What will be the initial investment in equipment? What will the operating cost be? Will irrigation pay over a period of time on my soil conditions and with the crops that I raise? How much increased returns might I expect? What type of equipment do I need? How do I operate and manage the system to get the most out of it?"

There are a number of places where a farmer may go to get the answers to all these questions. The county agricultural agent can get the assistance of district agricultural engineers and of specialists from the Departments of Agricultural Engineering and Vegetable Crops at Cornell University. The Soil Conservation Service is prepared to assist growers, and dealers and distributors of irrigation equipment also have men who are trained to help growers design and plan irrigation systems. It is also a good practice for a grower to talk to others who are irrigating under conditions similar to his.

Light-weight aluminum pipe is now used almost exclusively for the moveable main lines and laterals. The common length of pipe is 20 feet; but, for larger systems one may want to consider 30- or 40-foot lengths. The longer lengths are less expensive and save labor.

Permanent underground mains may be best where field boundaries are likely to remain the same and where the same fields are to be irrigated every year or nearly every year. They are more expensive to install but once properly installed will be out of the way and may save considerable labor over a period of years.

The water is distributed over the crop either by rotating sprinklers or by perforated pipe. The rotating sprinklers come in a variety of sizes. The nozzle tips can be changed so that almost any rate of dis-

charge can be obtained. Sprinklers discharging from 8 to 20 gallons per minute and operating at pressures from 30 to 50 pounds per square inch are the most common. Some tests have indicated that rotating sprinklers apply the water more uniformly than perforated pipe. They cover a larger area on each side of the pipe so fewer moves are needed. The perforated pipe applies water in a rectangular pattern and requires lower operating pressures and hence a slightly lower power cost. Perforated pipe drilled for low application rates is most desirable in New York State. This low-application-rate pipe applies water in smaller drops, which cause less compacting and puddling of the soil. It would be advisable to talk with growers who have used both systems before buying one.

The pump selected should have not only adequate capacity but should operate in the high efficiency range. If the pump is not operated efficiently, pumping costs will be higher. Horizontal centrifugal pumps are used when the water does not have to be lifted more than 20 feet. For greater lifts, a deep-well turbine is necessary.

Harvesting

CAREFUL handling of potatoes from the field to the consumer could eliminate many losses. Surveys of potatoes in city retail stores have shown that more than one-half of the damaged tubers reaching the housewife were injured at harvest time.

When to harvest

Potatoes should be dug after the vines have been dead at least ten days to two weeks. This allows the tubers to mature and become, therefore, less subject to skinning and bruising. Either skinning or bruising not only impairs the appearance of the potato but results in considerable loss through shrinkage and rot in storage.

Should the vines remain alive too late in the season or become infected with late blight, the use of mechanical or chemical vine killers is advised (below).

Destruction of vines

The most popular way to destroy vines is with mechanical beaters that shred the vines. This makes digging easier. Some growers use chemical dusts or sprays. In general, sprays have been more effective than dusts. Such materials as the Di-nitro compounds and sodium arsenite are used. Sodium arsenite is more effective when grass is a problem, but must be used at double the rate necessary to kill potato vines. If a slow kill is desired, copper sulfate at the rate of 30 to 35 pounds per acre is satisfactory.

Harvesting equipment

New York's potato crop is largely dug with one- or two-row diggers and picked up by hand. A small portion of the crop is handled with potato harvesters, which are either digger-sacking (or barrels) or digger bulk-handling units. There are several different types and models of harvesters; some developed, manufactured, and sold by equipment companies and others built by growers themselves.

Mechanical harvesters are becoming more popular because it is increasingly difficult to get efficient and reliable laborers to harvest the crop and because cost of labor is high. Many growers are looking for a satisfactory mechanical harvester. At present there seem to be no potato combine that works satisfactorily and efficiently under all of the conditions found throughout New York State. To do so it must be able to dig or pick up from a windrow, separate the potatoes from dirt, stones, dirt clods, vines, and trash in soils varying from muck to stony gravels and to deliver the potatoes to bags, barrels, or bulk trucks with a minimum of bruising. Also, it must have enough capacity and must operate efficiently enough so the harvesting cost per bushel will be less than when a conventional digger is used and the crop is hand picked.

When these requirements are considered, it can be seen that the task of developing a harvester is exceedingly difficult. Probably one single harvester may never work efficiently under all conditions but some one of the different types will be more satisfactory than another for a given set of conditions. Many of the harvesters do work quite satisfactorily on sandy loam soils but not too well under extremely stony conditions.

One fact that is all too frequently overlooked is the excessive amount of bruising and injury caused to the potato crop in harvesting and handling. Much of this injury is caused by improper adjustment of the diggers or combines and can be reduced. More attention should be given to combines than to diggers as there is a greater opportunity for bruising with combines because they have more conveyors and drops than do diggers. *Rough handling and mechanical injury produce grade reductions that few potato growers can afford.* About 10 per cent of the potato crop is damaged each year by improper adjustment of the harvesting equipment.

Causes of mechanical injury

Tubers are damaged when they strike a hard surface with considerable force, such as when bouncing on the digger chain, dropping on a metal conveyor, or hitting against a hard object when moving too fast.

Figure 15. A roto beater removing the vines from a field of potatoes on the Nat Talmadge Farm on Long Island

The bruise is not always apparent immediately but shows up later in storage as a cull or a U. S. No. 2 potato, or in the hands of the housewife. Much can be done to reduce mechanical injury to the potatoes by proper adjustment and operation of the harvesting machinery and equipment.

Vine removal

Various vine-removing machines if improperly adjusted cause some skinned and bruised tubers. Machines set low or flails not trimmed for the row so they beat into the row of potatoes knock off the soil and strike the tubers. The beater should not be adjusted so low that this happens. Vines are best removed when the flails just clear the ground.

Depth of digger point

Often the digging point cuts the tubers and causes injury. The point should be set deep enough to be well below the bed of earth in which the potatoes lie. The potatoes should be lifted by the point and transferred to the chain in a surrounding cushion of soil. This cushion of soil, traveling with the potatoes, prevents chain injury.

Ground speed

Far too many diggers are operated at from 2 to 3 miles an hour, resulting in costly injury to the potatoes. The tubers are damaged when they come into forceful contact with various parts of equipment being operated at these speeds. With equipment available today, diggers or harvesters should be operated between 1 and 1½ miles an hour. This means the digger travels between 90 and 130 feet in 1 minute. With potatoes planted in 36-inch rows, one could dig nearly ½ acre an hour with a single-row digger. Operating diggers faster than this increases the damage from about 2 to 10 per cent or more.

Digger-chain speed

Excessive chain speed is the most important single cause of tuber injury. This is borne out in table 1 which shows the relation between potato-digger adjustment and tuber bruising. As the potatoes go over the machine they accelerate from a stand still to the speed of the digger chain in a very short time. Unless the potatoes are cushioned with a

layer of soil against striking the chain they will be damaged. It is therefore important that the chain speed be no greater than 125 to 150 feet per minute, which is about eight revolutions of the digger chain per minute. A good guide is to watch the potatoes. If they bounce on the chain, the speed and agitation are too great. This can easily be determined by tying a marker to a link in the chain and begin digging at normal speed then to count the number of times the marker passes a given spot per minute.

Photo by E. S. Shepardson

Figure 16. Potatoes bruise unless there is a cushion of soil as they are carried back on the digging chain. Note the potatoes bouncing on the chain

Agitation of the chain

Excessive agitation also causes damage to potatoes while digging as is shown in table 2. The amount of agitation should be adjusted according to digging conditions. Agitation should be kept to a minimum. The soil should be carried at least two-thirds of the way back on the digger chain. The amount of agitation is determined by adding or removing the agitator or jump sprockets on each side of the chain. On at least

Table 2. Relation between Potato-Digger Adjustment and Tuber Bruising*

Factor affecting bruising	Degree of adjustment	Tubers bruised
		Per cent
Depth of digger point	Shallow	10.8
	Deep	4.2
Speed of digger chain	Fast	15.0
	Slow	1.4
Agitation of chain	Rough	4.5
	Gentle	0.75
Tension of digger chain	Loose	7.4
	Tight	3.2
Padding of deflectors	Not padded	9.0
	Padded	6.3

*Based on work done by the late Professor E. V. Hardenburg and Professor C. N. Turner, Cornell University.

one make of machine the amount of agitation is adjusted by a lever which moves the chain closer to or farther from the agitation sprockets by idlers.

Bruising caused by tubers striking the chain links can be reduced also by covering the links with rubber tubing. Soft rubber tubing with 1/8-inch side walls and 1/32 inch larger than the size of the chain link should be used. It is recommended that a soap solution be used as a lubricant for installing the rubber tubing and then cement the ends of the tubing to the link to prevent slippage.

Difficulty is encountered on some soils when trying to dig during extremely muddy conditions. The rubber-covered chain coats so badly with mud that it is impossible to use. It is a good idea to keep an uncovered chain handy for use in such emergencies.

Deflectors and sharp curves

Potatoes are also bruised when they strike a metal deflector, a sharp corner, or the raised portion of the digger-chain link ends. This can be eliminated by covering the deflectors with rubber tubing as shown in figure 17. Shields made of belting keep the potatoes from contacting the

Figure 17. Rear deflectors padded with rubber tubing to prevent bruising

link ends. The belting can be bolted to the sides of the digger and left to extend over the link ends of the chain. The chain can also be changed so the link ends are turned in. When this is done, one cannot use the cone-shaped idler at the lower end of the digger chain. Instead, a larger idler with straight sides should be substituted.

How to Reduce Mechanical Injury at Harvest

1. Set the digger points deep enough to eliminate sliced potatoes and so soil will be carried at least two-thirds of the way back on digger chain.
2. Reduce ground speed to about 1 to 1½ miles per hour.
3. Run digger chain as slow as possible – no more than 125 to 150 feet per minute or 8 revolutions of the chain per minute.
4. Pad chain links with rubber tubing.
5. Use a minimum of agitation and increase it only when soil and digging conditions demand.
6. Invert chain or use shields over end of links.
7. Pad deflectors and sharp objects with belting or rubber tubing.
8. Keep the digger chain reasonably tight to prevent sagging and whipping.
9. Pad the sacking platform and handle the sacks carefully.
10. Eliminate drops of more than 6 inches.
11. Do not walk on crates, bags, or piles of potatoes.
12. Exercise care in loading and handling.

Potato Storages

WHAT is the solution to the storage problem? Is it a new building, the conversion of an existing building, a rental storage, or selling the potatoes direct from the field? A properly designed storage should pay for itself through higher quality potatoes for the best available markets.

Types of storages

Climate and terraine are important considerations in deciding the type of storage to build. The type may also be influenced by existing buildings that are available for conversion. Three common types of storage are: (1) above ground, (2) partially below ground, and (3) below ground. In areas with warmer climates, such as Long Island, research shows that the above-ground storage is the most satisfactory. A well-insulated above-ground storage can be cooled much more rapidly in early fall with normal air-conditioning equipment than can the below-ground or partially below-ground storage. Refrigeration equipment

does not seem justified for the storing of potatoes alone for the normal holding period. Above-ground storages usually are limited to one floor.

Partially below-ground storages have received widespread usage throughout the State and are still popular. They are particularly adapted to upstate areas where temperatures at harvest time are considerably cooler than they are on Long Island. This makes it possible to cool the potatoes rather rapidly even though there is a considerable amount of ground heat in the lower level of the storage. In winter this ground heat helps to hold the storage temperature above freezing. A large proportion of the buildings available for conversion would fall into this class. The most common building for conversion is the basement dairy barn, which probably has one side in a bank. This type of storage requires a great deal of insulation on the above-ground side but very little, if any, on the bank side. This results in some saving in construction costs.

The below-ground storage should be used in the same way as the partially above-ground storage in areas where temperatures at harvest time are quite cool. This type of storage makes full use of the earth as an insulator and as a source of heat to maintain storage temperatures during the cold winter months.

Interior design

Interior design of the storage is important from the standpoint of efficiency of operation. The above-ground and below-ground storages normally have single floors, while the partially above-ground storage would be expected to have two or more floors.

The need for a grading room is a debatable question. A separate grading room may require more complicated conveying equipment than would otherwise be necessary. Such a room does, however, permit the workers to work in a warm area without increasing the temperature of the storage proper. It is possible to have considerably more storage space for the same cost if the grading is done within the storage rather than in a separate grading room.

Posts in the storage area give little trouble as far as the actual storage of potatoes are concerned but may hinder movement about the storage. The storage should have a minimum of posts to support the roof or have a trussed roof that requires no posts.

Location

A trackside location is no longer so important as it once was. It may be desirable for the really large producer or handler of potatoes but makes little difference to the smaller producer who transports the

greater proportion of his crop by truck. Location on a good hard-surface road is important to make the storage easily accessible and to aid in advertising the fact that potatoes are available for sale.

Construction materials

Wood, concrete, and concrete blocks are the common materials used for storage construction. Wood and concrete blocks are used for above-ground storages, while concrete and concrete blocks are used below ground. In any storage it is important to provide enough strength in the wall to stand either the outward pressure of the potatoes in above-ground storages, or the inward pressure of the earth in below- or partially below-ground storages. Cast-in-place concrete walls can be reinforced with reinforcing mesh or with reinforcing rods. Concrete-block walls must have buttresses for adequate support. The size of the buttresses can be greatly reduced if they are made with reinforcement. In storages of wood construction, the strength of the wall is provided in the size of the members used for studs. It is wise to consult a competent engineer to determine the required rigidity for the wall.

Enough insulation is required to prevent the storage from gaining heat in early fall and to prevent freezing of the potatoes during winter. Six inches of a good commercial type insulation is recommended for wall insulation in an above-ground or partially above-ground storage. Nine inches of shavings will also be satisfactory. The ceiling insulation should be about 25 per cent greater than that of the walls because there is always a greater heat loss through the ceiling than through walls. This means 12 inches of shavings or 8 inches of a good commercial type insulation. A good vapor-barrier material must be placed on the warm side of the insulation since the potato storage is maintained at a high humidity. Moisture moving into the insulation causes deterioration of structural members and reduces the efficiency of the insulation itself.

Management

The care which the potato receives during digging, loading, and storage is most important in determining the quality of the potato at the time it leaves the storage. Potatoes are loaded in storages in different ways: in bags, in bushels, and in bulk. Special care should be taken to limit as much of the bruising, cutting, and scraping as is possible. Many partially above-ground storages are of two floors, and the lower floor is loaded through holes in the upper floor. Potatoes should enter the lower part of the storage along an incline especially designed to prevent the potatoes from falling. The upper floor and single-floor

storages are often loaded with small conveyors. This same conveyor may be used to good advantage for unloading. Specially built ducts in the floor may be used for both unloading and for cooling and ventilating.

Prior to cooling the potatoes to the desired storage temperature, they should be maintained at a temperature of approximately 60° F. This serves as a healing period. Many times the healing period is considerably longer than it needs to be. Generally speaking, a period of two weeks is enough. Care must be taken with forced-air cooling to be sure that the potatoes have been properly healed before they are cooled.

Two methods are used to cool and ventilate potatoes. One is the so-called gravity system and the other is a forced-air system. The forced-air system has much to offer in that the air is passed around a great many more potatoes and cooling is more rapid than it is with the gravity method. The rate of cooling of non-refrigerated storages is definitely related to outdoor temperatures. A system has been designed which permits the entrance of outside air during the cooling period only when the outside temperature is lower than that within the storage. When the potatoes have been cooled to the desired storage temperature, this system operates on a recirculation basis. It blows air through the potatoes for a period of approximately 15 minutes each hour. This re-circulation maintains uniform storage temperatures and eliminates hot spots which sometimes occur with the gravity system. On warm days in the winter months when storage temperatures begin to rise, the system brings in a small amount of outside air to cool and at the same time recirculates a large proportion of storage air.

The gravity system utilizes wall ducts along the outside walls in which the air drops and moves under the pile through small ducts and up through the potatoes. Successful cooling is achieved with this system only when the outside temperature is considerably cooler than that within the storage. Air is admitted through intakes along the walls and passes down the wall through the floor flues under the potatoes and out the exhaust flue. Once the potatoes have been cooled to the desired temperature, the gravity system maintains some recirculation through the use of a cold area along the wall called a *condensation area.* Both the inlets and specially designed doors on the outtake flue must be closed at this time. This cold area cools the air which then drops along the wall and moves under the potatoes. As it warms from contact with the potatoes, it begins to rise and more cold air settles to take its place.

The desired temperatures for potato storage ventilation seems to be in the range of 36° to 40° F. Many storages are kept at 32° to 36° F. since they do not have enough insulation to hold them above that.

Storage temperatures below 34° F. may sweeten table stock and cause seed potatoes to sprout slowly.

When the potatoes have been cooled and stored for any length of time they should be warmed prior to grading or an increased amount of bruising and skinning may result. A temperature of 50° F. is adequate for potato warm-up. This warm-up takes place in storages with a gravity system when warmer weather approaches. Storages with the forced-air system have maintained desirable storage temperatures up until the first of May. Much more rapid warm-up can be obtained with the forced-air system than with the gravity type. With the forced-air system it is possible to use only those parts of the ducts over which the potatoes are desired to be warmed.

In brief

Well-planned and well-managed storages, along with good varieties, add up to greater potato profits for New York farmers. Considerable thought should be given to the above-ground storage in the areas with warm temperatures at harvest time. It is probable in most areas that farmers will be able to construct above-ground storages as cheaply as two-story partially above-ground storages or below-ground storages.

Cooking Quality

POTATO consumption in the United States has been decreasing gradually for some years, and reached a low of about 104 pounds per person per year recently. Undoubtedly the quality of the potatoes on our markets is one of the reasons for this decline in consumption. Other possible reasons are the notion that potatoes are fattening and many other competitive foods were not on the market until recent years. If the potato is to maintain its present rate of consumption or be increased, then some way will have to be found to make it as easily prepared for the table and as attractive to the consumer as are the many other new and convenient food items, such as canned and frozen foods, pre-prepared vegetables and other commodities. Such items as pre-peeled potatoes, canned potatoes, potato chips and sticks, frozen french fries, and dehydrated mashed potatoes help to fill this need.

"Beauty is only skin deep" never applied more appropriately than to our present-day potatoes. There has been no way by which the consumer could tell in advance what the cooking quality of any lot would be. Naturally, then, she chooses the potatoes that have the best appearance on the outside. This is, of course, varieties such as Chippewa, Katahdin, and Sebago, rather than Green Mountain, Rural, and Cobbler. Hence, the switch from mealy varieties to less mealy varieties. The

grower is easily converted to the newer varieties since yields usually are higher in many areas than from the older varieties.

Practically everything that has been done in the so-called improvement of potatoes has resulted in lowering their degree of mealiness. This, in no way, is criticism of potato breeders. Much research and commercial effort have been expended in dressing up the exterior of our potatoes by working toward brighter skin, shallower eyes, regular shape, and by sizing, better packaging, brushing, washing, waxing, and now, believe it or not, in some sections by dyeing them. But little has been done to improve the edible portion. In other words, a fairly good job has been done to dress up that part of the potato which usually goes into the garbage.

Where would the egg industry be today if poultrymen had followed such a program of improving the appearance of the shell, the inedible portion, and neglected the interior of the egg? Certain qualities of the edible portion of eggs were determined by the simple process of candling.

The determination of specific gravity, total solids, or starch content of potatoes by the potato hydrometer or some other methods is similar to the candling of eggs. By the method of separating potatoes with salt solutions into various specific gravity groups, one can now "gaze" into the interior of the potato and give consumers what they want in the way of mealiness of the cooked potato.

It is normal for potatoes to vary in specific gravity and mealiness; tubers from any one hill differ in this respect. Use of the specific gravity grader separates the non-mealy from the mealy potatoes in any lot regardless of variety or place where they are grown.

Although potato grades do not allow varietal mixtures, it is worse, as far as mealiness is concerned, to have in one package potatoes of one variety as they are normally grown than it would be to have several varieties in the same package but separated into one specific gravity group. It is just as important to have this separation as it is to have pastry flour and bread flour in separate bags.

How can our present potatoes better satisfy our consumers?

Determination of specific gravity or total solids content of potatoes by the potato hydrometer is an excellent, rapid way to determine mealiness of potatoes before they are cooked. This method could be used to locate lots of potatoes that are mealy and that could be especially advertised to emphasize their qualities for mealiness.

The potato hydrometer is being used by many potato-chip manufacturers since there is good relationship between the average specific

gravity of any lot of potatoes and the yield of chips obtained. Although this process of measuring the average specific gravity of lots of potatoes is helpful, the method of separating lots of potatoes by brine solutions into several specific gravity groups is still more valuable and far reaching. By this process, any lot of potatoes can be separated into groups and labelled according to their best cooking purpose, such as "Baking", "Boiling for mash potatoes", and "Will not fall apart when boiled."

Results of experiments where potatoes were separated into different grades of mealiness and sold in food stores show that consumers were willing to pay an additional price for the separated potatoes over those not separated. In the 1949–50 season when separated and unseparated potatoes were sold for the same price, 47.7 per cent of all experimental potatoes sold were Bakers; when the price of Bakers was increased 1.4 cents per pound above the price of unseparated potatoes, Bakers comprised 46.7 per cent of all experimental potatoes sold; and when the price was boosted to 1.8 cents per pound above the unseparated potatoes, Bakers made up 40.6 per cent of the sales. This shows that the consumers were willing to pay 7 cents more for 5 pounds of Bakers than for the same potatoes unseparated as to specific gravity without any reduction in volume of sales. Consumers also paid more for Boilers than for the same potatoes unseparated.

Results of a study in 1951 show that when prices were the same for Bakers, Boilers, and unseparated potatoes, Bakers and Boilers comprised 69 per cent of the experimental lots sold in six food stores. When a premium of ½ cent a pound was added for Bakers and Boilers, they comprised 65 per cent of the experimental lots sold; and when 1 cent a pound premium was charged for these lots, they still made up 62 per cent of all experimental lots sold.

These results show that consumers can now be supplied by using present varieties, with potatoes which, as far as mealiness is concerned, will perform as desired when cooked in the proper manner. The Bakers can be guaranteed to be mealy when baked or mashed and the Boilers can be guaranteed not to slough and fall apart when it is desired to serve a whole, boiled potato. Hotels and restaurants will often pay a premium to be assured of such potatoes, and consumers willingly pay for this guaranteed performance.

Factors affecting specific gravity and mealiness of potatoes

There is evidence that potatoes of the same variety have become less mealy during the past few years than they were formerly. Determination of specific gravity of thousands of samples of potatoes in New York

State during the past 14 years indicates that total solids content of potatoes during the past several years has decreased. Typical examples of the following potato varieties grown in the same location in 1940 and in 1950 are listed in the tabulation.

Variety	Average specific gravity	
	1940	1950
Pontiac....	1.081	1.071
Cobbler....	1.085	1.082
Katahdin..	1.092	1.083
Sebago....	1.098	1.082

Reasons for this decline are due largely to methods of growing potatoes today as compared with those of ten years ago. Some of the factors which affect mealiness of potatoes are as follows:

Variety. Many comparisons through a period of years show that when grown under the same conditions a variety such as Green Mountain is almost always the most mealy and varieties such as Essex and Pontiac are the least mealy.

To start a campaign of educating consumers as to the relative mealiness of the varieties grown and marketed, it would be well to stamp the name of the variety on each bag sold.

Soil moisture. In most instances, but not always, in seasons of high rainfall or in irrigated soils, potatoes are less mealy than in relatively low rainfall years or in unirrigated soils. In some years, potatoes grown in irrigated soils are more mealy than those grown in the same area without irrigation. This is true especially in hot seasons and is due primarily to the soil-cooling effect of the added moisture.

Soil type and location. Other things remaining the same, potatoes grown in muck soils are less mealy than those grown in the same area in mineral soils.

Amount and analyses of fertilizers. High amounts of nitrogen and potash usually result in less mealy potatoes. Phosphorus has little effect on mealiness of tubers.

Date of planting. If the season is near normal in temperature and rainfall, the earliest planted potatoes usually produce more mealy tubers than later planted ones, provided good care promotes late-season growth.

Date of harvest. If the plants are still green and functioning, the earlier the harvest, usually the lower the mealiness of the potatoes.

Temperature during the growing season, especially during the last few weeks. During periods of high temperature the mealiness of tubers harvested is lower than when the temperature is lower and more nearly ideal for the potato plant.

Maturity. Usually the more mature the potatoes are when harvested, the higher the degree of mealiness. This can be reversed, however, during periods of extra high temperatures, high moisture content of soil, and by other means.

Spraying program (fungicides and insecticides). Protecting plants from insect and disease ravages resulting in greatly prolonged growth of the plants quite often lowers the degree of mealiness of tubers. This results from immaturity of the plants. In some instances, however, the same spray program may result in increased mealiness of tubers by delaying their maturity from a very hot period in August or September to a cooler period in late September or October.

Killing vines. This operation in most instances in New York State has lowered the degree of mealiness as compared with natural maturity of the vines or of continued growth until frost.

The after-cooking blackening

The after-cooking blackening process is still not well understood. The following affects after-cooking darkening:

Variety. Some varieties, such as Bliss Triumph and Chippewa, have less darkening than some of the other varieties.

Growing season temperature, especially the last few weeks of the season. If temperatures are fairly high during the period of maturity, potatoes show less darkening than if they had matured during cooler temperatures, especially those under 50° F.

Sunshine. There is less darkening in potatoes when they are grown during seasons of ample sunshine than when grown during much cloudy weather.

Fertilizers. When heavy application of fertilizers, especially nitrogen, is made, the growing season usually is extended into the cooler portion of the fall and thus more discoloration results.

Maturity of vines and tubers. Any practice, such as applications of DDT to the vines, which prolongs growth into the periods of cooler temperatures, is likely to increase after-cooking darkening.

pH of the tuber. The more acid the tissue of the tuber, the less likely the tubers are to darken after cooking.

Marketing

To continue in the potato business, a farmer must have an income at least equal to his costs. He must market as well as produce efficiently. A large yield per acre of uniformly good-quality potatoes is the

first essential to satisfactory marketing. When the total late crop is very large or the price level of the country is falling, a grower faces a situation beyond his control.

Changes in supply and general price level

A very large United States crop of potatoes results in prices to growers below costs of production for all but the most efficient. Although consumption per capita (demand) dropped one-half over the first fifty years of this century, the decline was gradual and continuous and changes in supply were far more important on price than were the changes in demand. Potato growers, like other people, increase production when returns are favorable. This leads to years of over supply and prices for potatoes below the level of other farm products.

The effect of supply on price is illustrated by changes in the late 1920's and early 1950's. The total potato crop was less than 300 million bushels in 1925 and the New York average farm price was $2.11 a bushel. Growers increased acreage each year for three years, and the crop rose to 427 million in 1928 when the return to New York producers was only 66 cents a bushel. Conversely, the small crop of 1951 (325 million bushels) following the huge crop of 1950 (430 million bushels) resulted in a November farm price to New York growers of $2.92 a bushel as compared with $1.00 in 1950.

The influence of a change in the price level of the country is seen by comparing the farm price of $1.25 a bushel in 1927 when the total crop was 370 million bushels with only 40 cents in 1932 when the total crop was 375 million bushels. Prices received for farm products rise and fall sharply with any major change in the price level.

How are potatoes used?

In the early 1950's, around 260 million bushels of potatoes are needed for human use as fresh potatoes. About 27 million bushels are processed, largely as potato chips. Nearly 32 million bushels are used annually for seed, and a few million are exported. In large crop years, several million bushels are converted to potato starch in Maine and Idaho. The remainder is fed to livestock or thrown out.

Manufacturers of potato chips need good quality with particular characteristics. The volume of chips, frozen French-fries, and canned potatoes has been gradually increasing, and processed products have provided new market outlets for some producers. About three-fourths of the normal crop of potatoes is sold through wholesalers and retailers to eating establishments and homemakers.

Preference

Much has been said and written about consumer preference, but producers and shippers usually find a good market for clean, bright, sound potatoes of almost any variety. Some preference is shown for potatoes that bake well, but only a small proportion of the potatoes consumed are baked. Red varieties are popular with many homemakers in the midwestern markets and a smaller percentage of consumers in the Northeastern States. Homemakers prefer medium sizes, neither peewees nor jumbos. The larger sizes are preferred by some hotels and restaurants. Few potatoes command a premium price over the market unless they are superior in quality, size, and appearance.

Among the foods purchased by Americans, potatoes are relatively inexpensive. The price may fluctuate widely with large and small crops, but the quantity consumed changes but little with variations in retail prices. The most common protests by consumers are about dirty potatoes, those having cuts, bruises, and decay, and potatoes that cook dark.

Packages

The practice of marketing potatoes in pre-packaged 15-pound paper bags developed in the 1940's. More and more families have limited space for reserve supplies of food and no suitable place to store potatoes. In the larger cities, food purchases are frequent and in small quantities.

In 1948, the most common size of potato purchases in 1214 retail stores in New York City was 5 pounds. Consumer packaged potatoes were offered in 10-pound bags, but most of the sales were from bulk displays from which the consumer selected the quantity needed for only a few days. In most upstate New York stores, consumers commonly purchase potatoes in pre-packaged paper bags of 15 pounds.

Under New York State law, closed consumer packages must be marked with the name of the product, the weight, and the name of the packer. The quality in the bag when it reaches the consumer is one of the continuing problems facing the industry. Potatoes are perishable and bruising at time of grading or in handling may become decay when purchased for retail. A recent study of potato quality showed the increase in damaged potatoes from shipping point on eastern Long Island to New York City retail stores to be three times as great for potatoes in 5-pound as in 50-pound bags. Two days after packing, damaged potatoes amounted to 4.2 per cent and in another week it was up to 7.6 per cent of the total. These facts show the importance of care in grading and packing to prevent bruising.

Studies of costs of packaging in several States indicate that the 50-pound bag is the most economical, but few consumers buy 50 pounds of potatoes at one time. The cost of packaging in 15-pound bags was 25 per cent more per hundredweight than in 50-pound bags, and the cost in 10-pound bags was 64 per cent more.

The trend toward small purchases at retail to meet family needs for a few days at most is expected to continue. If consumers are as well satisfied with the potatoes in small closed bags as the bulk offerings, more of the crop will be sold in consumer packages. To get a premium for superior quality, a producer should pack to rigid specifications, identify his product, and keep it available to his buyers over as long a period as possible. Even though a reputation for good potatoes is established, it can be quickly lost if inferior potatoes are marketed under this brand or name.

Certified Seed Production

IN GENERAL, the term *certified seed potatoes* applies to potatoes that have been produced in fields which are subjected to routine inspections by competent and impartial inspectors and found to conform to specific standards. Standards may include requirements as to origin of seed planted, preliminary tests of the same, varietal purity, location of the field, amount of diseases present in the field and in the product, size and appearance of the potatoes themselves, and tests of samples of the seed. In New York the word *certified* is protected by law. Those growing certified seed must be members of the New York Certified Seed Growers' Co-operative. Standards are drawn up by the Co-operative, the College, and the State Department of Agriculture co-operatively, and are promulgated by the Commissioner of Agriculture. Inspection of samples and fields are made under supervision of the College of Agriculture and inspections of stock for sale, by the State Department of Agriculture and Markets.

The main purpose of the certification program is to provide the table-stock grower with sources of reliable seed, of desired variety, and free from injurious amounts of disease. The diseases involved are mainly leaf roll, mosaic, spindle tuber, yellow dwarf, ring rot, and verticillium and fusarium wilts. There is little possibility of controlling through certification such diseases as late blight, scab, rhizoctonia, black leg, purple top, and seed piece rot.

A person who wishes to grow certified seed and who is not already a member of the Certified Seed Growers' Co-operative should make application for membership as early in the previous winter as possible, certainly before the middle of May. He should obtain advice regarding

sources of seed from the chief inspector and protect this seed, when obtained, against contamination with ring rot from both known and unknown sources. This involves disinfestation of all equipment which is to come in contact with the new seed and which has previously been used for potatoes. If more than one source of seed is to be planted, precautions should also be taken against ring rot being transmitted from one lot to another, even though none is known to be present. The planter and the seed cutter are probably the most important pieces of equipment to keep clean. The discovery of even one plant or tuber affected with ring rot causes rejection. What growers often fail to realize is that this requirement does not constitute a guarantee that certified seed is free from ring rot, since some disease may be present in a given stock of potatoes for months or even years before it is discovered.

If the source of seed used is one not certified in New York, the grower will be required to submit a sample of it for test planting early in May. Inspection of plants produced by this sample and the results of two or more inspections of the field will be considered in determining whether the field is to be certified. The grower's fields for inspection should be separated from one another and from other potatoes by a space of one row. Each different variety is regarded as a different field. Rotation with other crops is not required but is highly desirable to prevent varietal mixture and as a partial control of such diseases as ring rot and verticillium wilt.

Application for inspection of the fields must usually be made by June 20. About five weeks after planting, the grower should go through his fields and rogue out any diseased plants. If he has had no experience in this kind of work, he may need help from some experienced person or should attend a roguing school. Effective roguing is greatly facilitated if the potatoes are planted by the tuber-unit method. Machines for this type of planting are now available. One model also treats the cut pieces and knives with a disinfecting solution, which is helpful in reducing the spread of ring rot and certain other diseases.

Certain diseases, of which leaf roll is the outstanding example, are carried from plant to plant by aphids. Usually, the newly infected plants do not show recognizable symptoms before they are mature but the tubers from them produce diseased plants. Sometimes, spread of this kind is so rapid that commercially damaging amounts of leaf roll occur in seed from certified fields. Recent indications are that much of this type of spread can be prevented by thorough and frequent applications of parathion to kill the aphids. At least 5 applications should be made. DDT is not effective for this purpose. Largely as a check on current season spread of leaf roll it is required that each certified seed

lot be sampled for testing during the winter by growing in Florida. This supplies information early in February of the disease content of the certified stocks and is of assistance in the selection of suitable lots for certification planting as well as for the elimination from certification of some unsuitable lots.

The final step in certification is the grading of the seed potatoes to comply with size and appearance requirements, attachment of certification tags, and inspection by the shipping point inspectors. It is important in these operations that injury to the tubers be kept at a minimum by warming the potatoes in advance of grading, by padding wherever needed, and by reducing the length of fall. Otherwise one may expect complaints of the rotting of tubers before planting time.

A publication of the
New York State College of Agriculture,
a unit of the State University of New York,
at Cornell University

Published by the New York State College of Agriculture at Cornell University, Ithaca, New York. L. R. Simons, Director of Extension. This bulletin is published and distributed in furtherance of the purposes provided for in the Acts of Congress of May 8 and June 30, 1914.